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Spacecraft L-Band Downlink to Receiving Earth Stations Interface Control Document

22 April 1996

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**SeaStar SPACECRAFT L-BAND DOWNLINK
TO RECEIVING EARTH STATIONS
INTERFACE CONTROL DOCUMENT**

SeaStar™
SPACECRAFT L-BAND DOWNLINK
TO
EARTH RECEIVING STATIONS
INTERFACE CONTROL DOCUMENT

22 April 1996

Prepared By:

Orbital Sciences Corporation
Space and Electronics Systems Group
21700 Atlantic Boulevard
Dulles, Virginia 20166

Approved By:

Pat Leygraaf
Orbital Sciences Corporation
Program Manager, Ground Segment

John McCarthy
Orbital Sciences Corporation
Program Manager, SeaStar

Howard Runge
Orbital Sciences Corporation
Deputy Program Manager, SeaStar

Mary Cleave
NASA / Goddard Space Flight Center
Project Manager, SeaWiFS

Released by:

Cynthia Padavano
Orbital Sciences Corporation
Configuration Manager, SESG

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1.0 INTRODUCTION

This Interface Control Document (ICD) defines the Radio Frequency (RF) and functional interfaces between Orbital Sciences Corporation's ("OSC") SeaStar satellite and Earth stations that receive real-time data on the L-band downlink.

This document assumes the spacecraft is operating in nominal imaging mode, so does not detail other operating modes such as calibration or contingency modes.

The two main interfaces relevant to receiving SeaStar's L-band direct downlink are the RF data downlink interface and the SeaStar Ground Processor (SGP) unit interface. This document details the RF data downlink and gives an overview of the SGP unit. Detailed information on the SGP unit is included in the document, SeaStar Ground Processor (SGP) Hardware Description and Users Manual, OSC Document Number, TD-1929.

1.1 Background

OSC has designed, produced and will operate the SeaStar spacecraft in compliance with National Aeronautics and Space Administration (NASA) contract NAS5-31350. If there are any conflicts between this document and this contract, the contract shall take precedence. This contract is managed by the Goddard Space Flight Center (GSFC) in Greenbelt, Maryland. Under this Contract OSC is required to provide NASA with ocean color data for the contractual period of five years. An illustration of the main elements of the SeaStar/SeaWiFS system is provided in Figure 1.

To fulfill this requirement OSC has designed the SeaStar spacecraft, which is dedicated to the Sea-viewing Wide Field-of-view Sensor (SeaWiFS) instrument. The SeaWiFS instrument provides Earth surface color data using six visible and two near-infrared spectral bands. The SeaStar spacecraft provides Earth surface color imagery in two modes, Local Area Coverage (LAC) mode with a spatial resolution of 1.1 km and Global Area Coverage (GAC) mode with a spatial resolution of 4.5 km. The L-band direct downlink contains LAC SeaStar data. The GAC data will be downlinked at S-band direct to NASA's facility at Wallops Island, Virginia. The overall parameters of the SeaStar spacecraft are given in Tables 1 and 2.

The SeaStar contract between OSC and NASA is structured such that NASA has the research rights to SeaStar data for the contractual period of five years. OSC retains the operational and commercial rights to SeaStar data for the contractual five years and has full rights to the data collected after the first contractual five years are completed. To support this division of rights, the imagery field of SeaStar's L-band downlink is scrambled. All users who wish to receive and descramble the L-band data must utilize the SeaStar Ground Processor (SGP) obtained via a licensing agreement with OSC's wholly owned subsidiary, Orbital Imaging Corporation (ORBIMAGE), or with NASA through the research user approval process. The SGP performs descrambling in either real-time or on a delayed basis. The unit can be operated in real-time by commercially-licensed users and a limited number of designated NASA research users. For the remainder of the NASA-designated receiving stations the required descrambling information will be transmitted after no longer than a 30-day delay.

Figure 1. SeaStar / SeaWiFS Major Elements and Interfaces

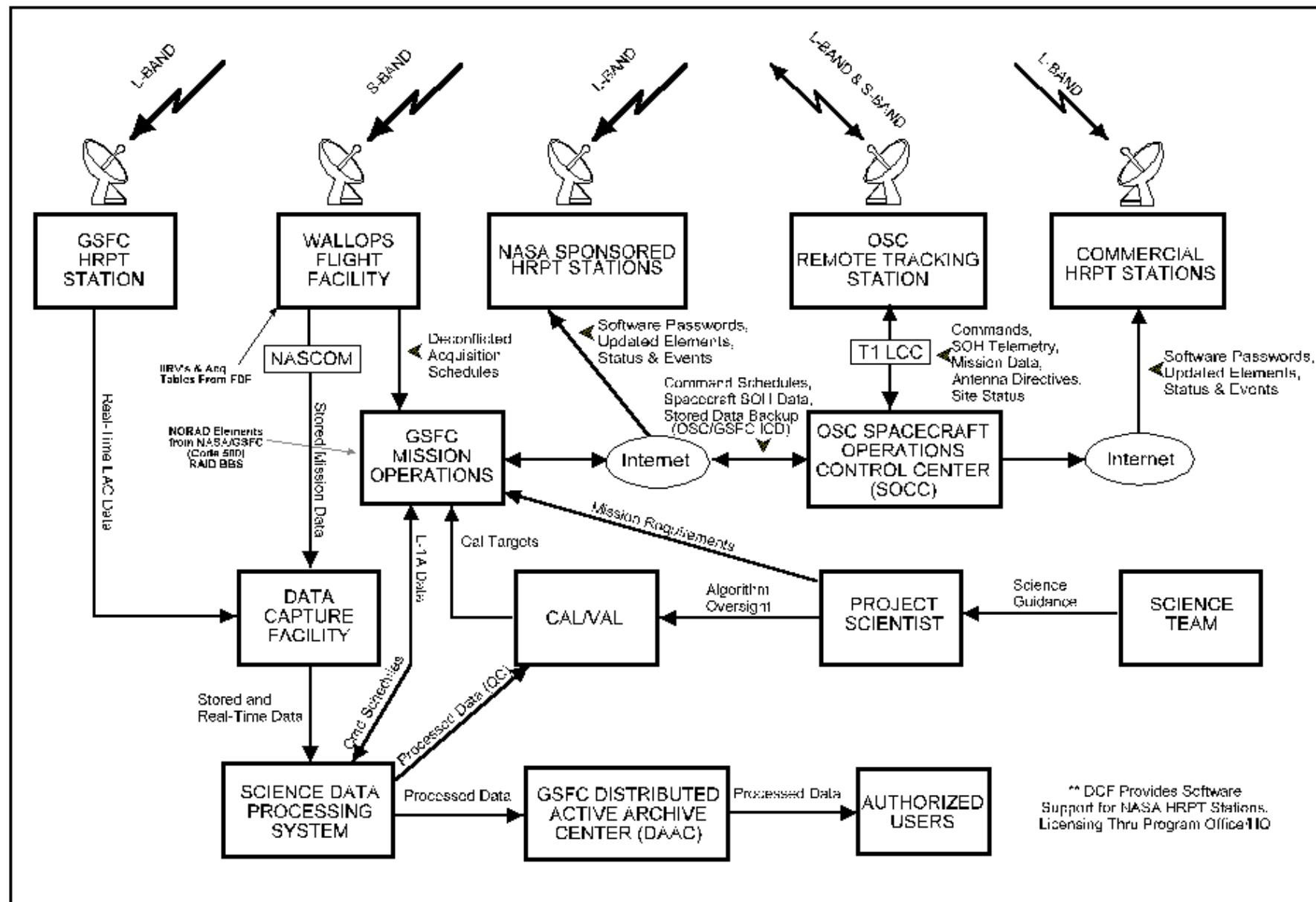


Table 1. SeaStar Mission Parameters

ITEM	DESCRIPTION
Orbit Altitude	705 circular km
Inclination	98.2 degrees
Type	Sun synchronous
Orbit Period (minutes)	99
Ascending Node Crossing Time	12 midnight ± 20 minutes
Descending Node Crossing Time	12 noon ± 20 minutes
Sensor Type	Scanning Radiometer
Number of Spectral Bands	8
Instantaneous Field of View (per pixel)	1.6 X 1.6 mr (milliradians)
Nadir Pixel Ground Coverage	1.1 km X 1.1 km
Digitization (per pixel)	10 bit
Pixels Per Scan Line	1288 total (1285 pixels of image data plus 1 start, 1 dark restore and 1 stop pixel)
Scan Rate	6 scan lines/sec
Scan Direction	West to East
Nominal Pointing Direction	Nadir
Scan Angle	± 58.3 deg from nadir
Scan Swath Width at Equator	2,800 km
Tilt Capability	3 Positions: Nadir (0 deg), 20° forward and 20° aft
Imaging Duty Cycle	On for 40 minutes in sunlit side of orbit, non-imaging for rest of orbit

Table 2. SeaStar/SeaWiFS Spectral Bands

Band	Wavelength [nm]
1	402-422
2	433-453
3	480-500
4	500-520
5	545-565
6	660-680
7	745-785
8	845-885

2.0 L-BAND DATA DOWNLINK

The SeaStar spacecraft has four main operating modes, the nominal mode, the contingency mode, the lunar calibration mode and the solar calibration mode. SeaStar will be in the nominal imaging mode providing a continuous downlink of full-resolution LAC imagery during the sun lit portion of the spacecraft's orbit. With regard to the contingency mode, after SeaStar is declared operational, the contingency mode will be used only if significant operational anomalies are encountered. The calibration modes will be used only when the spacecraft is in the non-imaging portion of the orbit.

This document is intended to provide information relative to receiving SeaStar's full resolution LAC imagery over the L-band direct downlink; therefore, the nominal mode of operation is emphasized. Section 2.1 details the data downlink format of the nominal mode, and Section 2.2 provides the top-level RF parameters for the nominal and contingency modes and references the RF link budget analysis for the nominal mode given in Appendix C.

2.1 Data Downlink Format

SeaStar's L-band direct downlink is very similar to the High Resolution Picture Transmission (HRPT) format used to transmit the full resolution imagery produced by the National Oceanic and Atmospheric Administration's (NOAA) TIROS satellite series. SeaStar's L-band direct downlink format was designed to be similar to NOAA's HRPT format so existing HRPT direct downlink receiving stations can be configured to receive SeaStar data with only limited modifications.

As with the HRPT downlink format, SeaStar's format has three minor frames per major frame with a synchronous serial data stream at 665.4 kbps with a minor frame size of 11,090 10-bit words. Also, SeaStar's frame synchronizer field and auxiliary frame synchronizer fields are equivalent to NOAA's HRPT data and SeaStar's identification and time code fields use the same format as NOAA's HRPT data downlink.

SeaStar's direct downlink data format is detailed in Appendix A. A summary of the timing and navigation information to support receiving and processing SeaStar's L-band downlink imagery data is given in sections 2.1.1 and 2.1.2. A summary of the image data field available in the direct downlink is given in section 2.1.3.

2.1.1 Timing Information Summary

SeaStar's L-band downlink contains time parameters that can be used to help determine the ground location of the image data. These parameters are described in detail below:

2.1.1.1 Frame Time Tag

Description: The Frame Time Tag is an absolute time tag using the Universal Time Coordinated (UTC) system. It is identical in format to the frame time tag used on NOAA's HRPT downlink. The Frame Time Tag corresponds to be beginning of the "start" pixel (the first pixel) of imagery data in each minor frame. This time tag is located in the third field of each minor frame (Ref. Figure A-1). The detailed description of this time tag is provided in page 1 of Table A-1 and in Figure A-2. This time tag is updated every minor frame (6 times per second).

Accuracy: The Frame Time Tag is accurate to \pm 25 milliseconds with respect to UTC time.

2.1.1.2 Image Data Time Tag

Description: The Image Data Time Tag is a millisecond counter that corresponds to the end of the “stop” pixel (the last pixel) of imagery data in each minor frame. This time tag is located at the front of the instrument telemetry field (ref. Figure A-1 and Table A-3). The detailed description of this time tag is provided at the top of Table A-3. This time tag is updated every minor frame (6 times per second).

Accuracy: The Image Data Time Tag is accurate to ± 2 milliseconds with respect to UTC time.

Relationship To Frame Time Tag: The spacecraft’s on-board GPS receiver provides a pulse per second (PPS) signal at the start of each integer second of UTC to synchronize the millisecond counters of the various spacecraft clocks. When the PPS signal is received, the millisecond values of the clocks are reset to 000 milliseconds. This process synchronizes the millisecond counters of the Image Data time tag and Frame time tag every integer second to the millisecond level. This synchronization and the high accuracy of the Image Data time tag can be used to provide a high accuracy UTC time tag on the image data as follows: Define Imagery Time as a UTC time stamp applied to the image data at the end of the “stop” pixel in each minor frame (same time reference as used for the Image Data Time Tag). The Imagery Time is calculated from the following relationships:

$$\begin{array}{lll} \text{Imagery Time} & \text{Frame Time} & + \text{Image Time Tag (msec)} \\ = & & \\ (\text{UTC, msec}) & (\text{UTC, Truncated to the Last Integer Second}) & \end{array}$$

However, if the PPS signal resets the Image Time Tag millisecond counter before the end of the minor frame’s image data (determined when Image Time Tag < 55 msec*), the following relationship replaces the one above:

$$\begin{array}{lll} \text{Imagery Time} = & \text{Frame Time} & + 1.000 \text{ sec} + \text{Image Time Tag} \\ & & (\text{msec}) \\ = & & \\ (\text{UTC, msec}) & (\text{UTC, Truncated to the Last Integer Second}) & \end{array}$$

* Note: This is the time it takes for the SeaWiFS to make one scan line of 1288 pixels. This value may change slightly (1-2%) with time as the sensor operates on orbit. When using this algorithm, use a secondary check on image time tagging to verify each minor frame time tag increments by 1/6 second. This will avoid one second jumps in the Imagery Time if the 55 msec drifts slightly.

Pixel Time: The time at the center of each pixel in the data stream (numbered from 1 to 1288) is determined from:

$$\begin{array}{lll} \text{Time Of Pixel N} = & \text{Imagery Time} + (\text{N} - 1288.5) * \text{Tpixel} \\ (\text{UTC, msec}) & (\text{UTC, msec}) & \end{array}$$

where **N** = number of the pixel in the minor frame’s image data field (numbered from 1 to 1288) and **Tpixel** = 0.042 msec ($\pm 1\%$)

2.1.1.3 Spacecraft Attitude and State Vector Time Tag

Description: The Spacecraft Attitude and State Vector Time Tag is also called the “ACS_Reference_Time.” Its format is defined in Table A-2. The Spacecraft Attitude and State Vector Time Tag corresponds to time when the spacecraft’s attitude control subsystem (ACS) calculates the attitude and state vector variables defined in Table A-2. This time tag is located in the spacecraft state of health (SOH) field in the first minor frame of each major frame (ref. Figure A-1 and Table A-2). These parameters are calculated every 2 seconds by the ACS, so the same values are repeated in successive minor frame 1’s until the next calculated update.

Accuracy: There is one time tag that is applied to both the spacecraft attitude and state vector parameters. However, the accuracy of this time tag is different for these parameters. When applied to the spacecraft attitude variables, (pitch, roll and yaw angles and corresponding angular rates), the time tag is accurate to better than ± 166 milliseconds with respect to UTC time. This tolerance is associated with processing of the ACS sensor data and applying the time stamp to the calculated results. Fortunately the change in attitude variables as a function of time occurs at very low rate (typical pitch rate is 0.06 deg/sec). So this tolerance is a small component of the pointing knowledge budget. When applied to the spacecraft state vector variables (X, Y and Z position and velocity of spacecraft in GCI coordinates), the time tag is accurate to ± 2 milliseconds with respect to UTC time. This high accuracy is possible because the ACS can accurately propagate the state vector variables provided by the GPS receiver.

2.1.2 Navigation Information Summary

2.1.2.1 State Vector and Attitude Parameters

The State Vector and Attitude parameters, along with the SeaWiFS tilt position, should be used for geo-locating the image data. The State Vector and Attitude parameters are included in the L-band direct downlink data stream as described in Table A-2. They are calculated in real-time by SeaStar’s Attitude Control Subsystem (ACS) using inputs from the ACS sensors and on-board Global Positioning Subsystem (GPS). Updates are provided every 2.0 seconds in minor frame 1 of the HRPT data. Since this minor frame is sent twice per second, the state vector data is repeated multiple times before the next update occurs.

2.1.2.2 SeaWiFS Tilt Position Data

The SeaWiFS tilt position telemetry is provided in the L-Band direct downlink data stream as described in Table A-3. During normal operations, the SeaWiFS scanner is kept in the 20° aft tilt position from the start of the imaging pass in the northern hemisphere until the spacecraft begins to cross the ecliptic plane. At that time, the scanner is commanded to the 20° forward tilt position for the rest of the imaging pass. The transition from aft to forward tilting takes about 13 seconds.

2.1.2.3 Two Line Element Sets (TLES)

The TLES data should be used for acquisition and tracking of the spacecraft by the ground station antennas. It will use the standard NORAD TLES format and be available directly from both OSC and NASA as described in Section 3.0.

2.1.3 Image Data Summary

2.1.3.1 Gain and TDI Telemetry

SeaWiFS uses four separate detectors for sensing each of the eight spectral bands (32 detectors total). A time delay and integration (TDI) technique is used to add the measurements of the four detectors to improve the signal to noise ratio. Any combination of the four detectors, including the ability to map out individual detectors, will be selected by NASA specified TDI settings. NASA will also be specifying which of the commandable gain settings will be selected for each channel. The values of the gain and TDI settings are provided in the 80 bits of telemetry located just in front of the image data (ref. Figure A-1). The specific gain and TDI telemetry codes are defined in Appendix B.

2.1.3.2 Image Data

Each imaging scan line consists of 1,288 blocks of 80 bit data. The first 80-bit block is the “start” pixel, the second 80-bit block is the “dark restore” pixel. The next 1,285 80-bit blocks are image data (8 bands, 10 bits per band numbered consecutively). The last 80-bit block in the image data is the “stop” pixel. The start, dark restore and stop pixels are described in Table A-5. A diagram of the image data field is given in Figure A-4.

The conversion of digital counts in the image telemetry to radiance values is dependent on the sensor calibration and the NASA specified gain and TDI settings. These parameters are likely to change over the course of the mission so they are not included in this document. For further information on the sensor accuracy and calibration data, refer to NASA Technical Memorandum 104566 accessible via the NASA/GSFC SeaWiFS Project Home Page at <http://seawifs.gsfc.nasa.gov>. The most recent calibration data will also be available through NASA’s SeaWiFS Home Page.

2.2 RF Downlink Parameters

The nominal mode L-band downlink parameters are given in Table 3. Sample L-band nominal mode link budget analyses are included in Appendix C. The link budget analyses are given for two receiving stations, OSC’s Tracking, Telemetry & Control station in Fairmont, West Virginia, and a NASA specified HRPT ground station.

Table 3. Nominal Mode L-Band Downlink Parameters

ITEM	DESCRIPTION
Frequency:	1702.5 MHz \pm 100 kHz (max frequency drift over lifetime)
Doppler Shift :	\pm 46.5 kHz (must be compensated by ground station)
Bandwidth:	1.5 MHz (-3dB)
Modulation:	Phase Modulation (\pm 67.5 ° PM) \pm 7 ° Tolerance
Polarization:	Right Hand Circular
Digital Format:	Bi-Phase L (Manchester 1-1)

Data Rate:	665.4 kbps
------------	------------

The contingency mode L-band downlink parameters are given in Table 4. This table is given as supporting information. The contingency mode is used only for spacecraft contingency operations and does not transmit any image data.

Table 4. Contingency Mode L-Band Downlink Parameters

ITEM	DESCRIPTION
Frequency:	1702.5 MHz \pm 100 kHz (max frequency drift over lifetime)
Doppler Shift :	\pm 46.5 kHz (must be compensated by ground station)
Bandwidth:	120 kHz (-3dB)
Modulation:	Phase Modulation (\pm 67.5 ° PM) \pm 7 ° Tolerance
Polarization:	Right Hand Circular
Data Rate:	57.69 kbps
Digital Format:	Bi-Phase L (Manchester 1-1) without P/N Randomization with HDLC Framing

3.0 OTHER SOURCES OF NAVIGATION INFORMATION

In addition to the state vector navigation information available in the L-band direct downlink, OSC and NASA will generate Two Line Element Sets for the SeaStar spacecraft. OSC's element sets will be updated on a weekly basis and be available through OSC's ORBIMAGE Home page, <http://www.orbimage.com>. NASA's element sets will be available through NASA's SeaWiFS Project Home Page, <http://seawifs.gsfc.nasa.gov>. They are also available through anonymous ftp.

For access, type:

```
ftp manua.gsfc.nasa.gov  
(enter "anonymous" for username)  
(enter your e-mail address for password)  
cd pub/mission-ops  
get selDDDYY.dat  
      (where DDD is day-of-year (1-365) and YY is last 2 digits of year)  
or  
prompt  
mget sel*  (this will transfer all the selDDDYY.dat files)  
quit
```

NASA has developed an orbital prediction software package for SeaStar called SeaTrack. This program accepts a TLES input, propagates the orbit and produces ground station acquisition parameters useful for tracking the satellite. A description of SeaTrack as well as the definition of the Two Line Element Set format is given in the NASA Reference Publication 1331, December 1993, *SeaTrack -- Ground Station Orbit Prediction and Planning Software for Sea-Viewing Satellites*, by Kenneth S. Lambert, Watson W. Gregg, Charles M. Hoisington, and Frederick S. Patt. This software is available on the SeaWiFS Project Home Page or through anonymous ftp. Used the same access directions listed above for the TLEs, but instead, type:

```
prompt  
mget seatrk*  
quit
```

4.0 SEASTAR GROUND PROCESSOR (SGP)

This section gives an overview of the SeaStar Ground Processor (SGP) unit. Details of the unit are included in the SGP User's Manual (OSC Document TD-1929) available from OSC (see section 6.0 for contact).

4.1 SGP Operations

Real-time image data from the SeaWiFS instrument is encoded on-board the SeaStar spacecraft and downlinked at L-band during nominal operations. No other portions of the data are scrambled. The contingency mode downlink contains no SeaWiFS HRPT image data and is not scrambled.

L-band data transmitted during nominal operations may be descrambled by receiving Earth stations in real-time or on a delayed receipt basis, depending on licensing or NASA designation. Data descrambling by Earth stations is performed utilizing the SeaStar Ground Processor (SGP) unit. The unit is designed to utilize existing interfaces in most High Resolution Picture Transmission (HRPT) stations and is physically located between the bit synchronizer and frame synchronizer as shown in Figure 2.

The bit synchronizer provides a synchronous, NRZ-L serial data stream at 665.4 kbps using HRPT frame synchs, time tag, scrambled SeaWiFS image data, and spacecraft ID fields. For real-time data users the SGP descrambles the incoming SeaWiFS image data and outputs it as an NRZ-L serial data stream at 665.4 kbps to the frame synchronizer. For delayed-data users, the SGP stores the incoming scrambled HRPT data stream to a SCSI-2 IBM™ PC disk drive or any other SCSI-2 compatible storage device. After the correct password is input to the SGP, the user can REPLAY the stored HRPT data stream back through the SGP SCSI-2 port for descrambling of the SeaWiFS image data field. Again, the SGP outputs the HRPT descrambled serial data stream consisting of HRPT frame synchs, time tag, descrambled SeaWiFS image data and spacecraft ID fields to the frame synchronizer.

Each station is required to input a unique software password consisting of 16 hexadecimal characters into the SGP. This can be done manually via the front panel keypad or locally using an IBM™ compatible PC connected to the port of the SGP. OSC will change the encoding algorithm on-board the SeaStar satellite and provide a new password to each HRPT receiving station at two week intervals via the ORBIMAGE Home Page, <http://www.orbimage.com>. For real-time research users the password is provided by OSC two weeks prior to the effective period to allow processing the SeaWiFS color image data as soon as transmission is received. Delayed-data users receive the software password no later than 30 days after the software password is first effective. This requires delayed-data users to provide a computer and mass storage device in addition to the OSC-provided SGP to store the data until the effective software password is received. The SeaWiFS project office at NASA Goddard Space Flight Center requires NASA research users to store their processed SeaStar data on a 4-mm Digital Audio Tape (DAT) device.

4.2 SGP Physical Description

The SGP is housed within a 19" x 17" x 5 1/4" black anodized aluminum enclosure. It can accept an AC Power input between 90VAC to 240VAC, 50/60Hz. The SGP is designed to "Best Commercial Practice" and operates over a temperature range from 0°C to 50°C. Incorporated within the SGP is an integrated power module including a high-performance EMI filter which meets or exceeds FCC Part 15J - Class B for emission control and an AC power switch and in-line fuses. The SGP is powered by a Universal Switching Power Supply rated at 5VDC/5AMPS.

4.3 User Supplied Equipment Requirements

To accommodate the storage and replay modes, the SGP box must interface to a PC-type computer. To handle the real-time sustained data transfer rate, and to run the OSC-provided software, the user-supplied IBM™ compatible PC must meet the following minimum requirements:

1. An IBM™ compatible PC 486DX/33MHz (ISA or EISA)
2. 4 Mbytes RAM
3. Standard serial communicator port (RS-232C)
4. SCSI-2 controller cards (recommend Adaptec™ 154X, 1640 or 174X using ASPI drivers)
5. 200 Mbyte SCSI hard drive with 13 ms access
6. DOS 5.0 or later
7. Monitor and video board configuration are left to the individual users.

The PC and mass storage device must incorporate all required file management software. OSC-provided software will only handle the SGP modes and data ingest and storage/retrieval to/from the hard drive. The user must off-load the data from the hard drive to the mass storage device. The 200 Mbyte hard drive is large enough to store one day's worth of LAC data (assuming two 15 minute passes per day) and to host the OSC-supplied software and user-supplied file management software. The mass storage device should be capable of storing a 30-day period of SeaStar LAC data.

Total Storage Capacity: 5 Gbytes (assuming two 15-minute passes per day over a 30 day period with 10% margin -- actual storage requirement depends on station location and visibility)

The SGP does not require a specific mass storage device. However, it must have the necessary storage capacity and file management software. The SeaWiFS project office at NASA GSFC requires NASA-sponsored users to store their processed data on a 4mm Digital Audio Tape (DAT) device. Commercial vendors may utilize any appropriate storage device with file management software.

4.4 SeaStar Ground Processor Interfaces

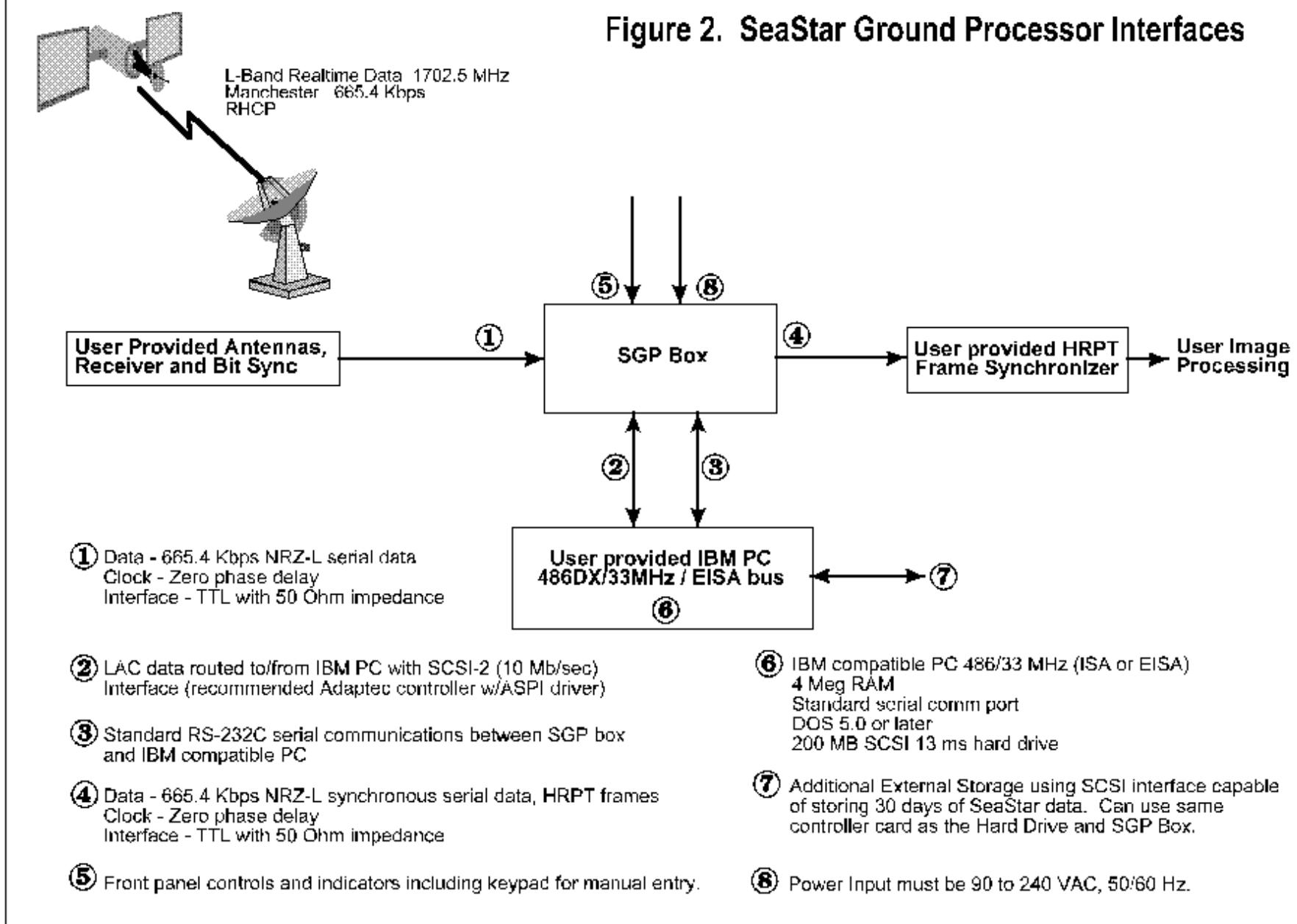
Interfaces to the SGP include: bit synchronized data and clock, an IBM™ Compatible PC interface, operator inputs and electrical power. Output is a serial data stream and clock compatible with the HRPT standard format. SGP interfaces are summarized in Figure 2. Detailed information on these interfaces is provided in the SGP User's Manual (see section 4.0).

4.5 Data Format (output from SGP box)

The SGP box outputs the nominal L-band HRPT frame format with the LAC data descrambled. Appendix A contains a diagram of the SeaStar frame format and a description of each of the fields within the frame. The SGP provides data and clock (TTL data and zero-phase delay clock with a nominal impedance of 50 Ohms) in HRPT frame format:

- 11,090 words per Minor frame
- 10 bit word format
- HRPT frame sync and aux sync
- HRPT time code and spacecraft ID field
- Three minor frames per major frame
- Two major frames per second
- 665.4 kbps data rate

Figure 2. SeaStar Ground Processor Interfaces



5.0 OPERATIONAL INFORMATION

OSC's wholly-owned subsidiary, Orbital Imaging Corporation (ORBIMAGE), will provide operational information on SeaStar via the Internet World Wide Web Home Page, <http://www.orbimage.com>. Information available at this home page includes:

1. Spacecraft Operational Mode Status
2. Two-Line Element Sets
3. SeaStar Ground Processor Unit User Passwords

6.0 ADDITIONAL INFORMATION

For additional information or direct questions concerning SeaStar data licensing or the SeaStar program, please contact OSC's wholly owned subsidiary, Orbital Imaging Corporation (ORBIMAGE), Customer Service Office at:

SeaStar Customer Services Office
Orbital Imaging Corporation
21700 Atlantic Boulevard
Dulles, Virginia 20166
Phone: (703) 406-5000
Fax: (703) 406-5552
E-mail: marketing@orbimage.com
Home Page: <http://www.orbimage.com>

APPENDIX A

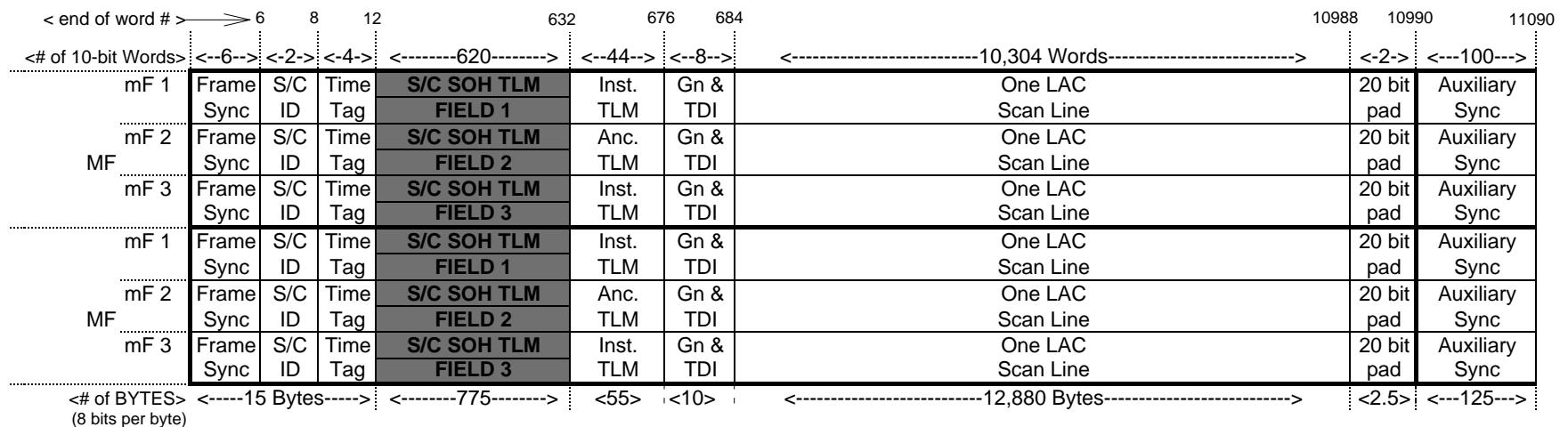
DIRECT DOWNLINK FORMAT DESCRIPTION

This Appendix details SeaStar's L-band direct downlink format. The overall format of a major frame is give in Figure A-1. An overview of the minor frame parameters is given in Table A-1 with additional detail on specific minor frame data fields given in Figure A-2 through Table A-4. A listing of the Figures and Tables in this Appendix is as follows:

- Figure A-1: L-Band Direct Downlink Format Overview
- Table A-1: L-Band Direct Downlink Format Description
- Figure A-2: Minor Frame Time Code Format
- Table A-2: State Vector Variables
- Table A-3: Instrument Telemetry
- Table A-3A: SeaWiFS Analog Telemetry Valid Range
- Figure A-3: Imagery Field Definition
- Table A-4: Imagery Field Auxiliary Information

Figure A-1. L-Band Direct Downlink Format Overview

One Second of Real-Time Stream (Two Major Frames):



White: 10-bit Telemetry Format
Shaded: 8-bit Telemetry Format

Note:

Minor frame is 11,090 10-bit words (13,860 bytes + 20 bit pad)

Three minor frames per major frame

Two major frames per second

Words:

10 bit format (except shaded area)

Bit 1 = MSB, Bit 10 = LSB

Bit 1 transmitted first

Table A-1. L-Band Direct Downlink Format Description

Field	No. of * Words in Field	Position ** within Minor Frame (Words)	Position** within Field (Words)	Position** within Word (Bits)	Description	Additional Detail
Frame Sync	6	1	1 2 3 4 5 6		1 0 1 0 0 0 0 1 0 0 0 1 0 1 1 0 1 1 1 1 1 1 0 1 0 1 1 1 0 0 0 1 1 0 0 1 1 1 0 1 1 0 0 0 0 0 1 1 1 1 0 0 1 0 0 1 0 1 0 1	Consists of first 60 bits from a 63-bit PN generator started in the all 1's state. Generator Polynomial: $X^6+X^5+X^2+X+1$. Register reset to all 1's for next minor frame.
Spacecraft Identification (and Data Type)	2	7	1 2	1 2-3 4-7 8-10 1-6 7-10	0 Frame ID (01 = minor frame 1; 10 minor frame 2; 11 = minor frame 3) 0010 = Spacecraft Address 011 = spare 000000 = spare 0000 = Nominal LAC 0010 = Solar Cal. 0100 = TDI Check 0001 = Lunar Cal. 0011 = Intergain Cal. 1111 = GAC	
Frame Time Tag	4	9	1 2 3 4	1-10 1-3 4-10 1-10 1-10	Binary Day Count (Bit 1 = MSB) Binary Day Count (Bit 3 = LSB) Conversion: Day Count = Julian date - 2,449,000.5 Binary "msec of day" count (Bit 4 = MSB) Binary "msec of day" count Binary "msec of day" count (Bit 10 = LSB) Conversion: msec count = milliseconds since midnight UTC Time Reference: First bit of first imagery pixel in minor frame. (see section 2.1.1)	Figure A-2.

Table A-1. L-Band Direct Downlink Format Description

Field	No. of * Words in Field	Position ** within Minor Frame (Words)	Position** within Field (Words)	Position** within Word (Bits)	Description	Additional Detail
Spacecraft State of Health Telemetry	620	13			One complete major frame includes all spacecraft state-of-health telemetry. This document only describes the spacecraft state vector and attitude data needed to geo-locate the image data. These are located in minor frame 1 as shown in Table A-2. (Bit Ordering: MSB-FIRST, LSB-LAST)	Table A-2.
Instrument Telemetry	44	633	1-4 5-7 8-39 40-44 1-44		<u>Minor Frames 1 and 3</u> Instrument Time Tag Discrete Telemetry Analog Telemetry (Bit 1 = MSB, Bit 8 = LSB) Spare <u>Minor Frame 2</u> 0 0 1 0 0 0 1 0 0 0 1 0 . . . 0 0 1 0 = fill pattern - “Anc.TLM” no longer used	Table A-3.

Table A-1. L-Band Direct Downlink Format Description

Field	No. of * Words in Field	Position ** within Minor Frame (Words)	Position** within Field (Words)	Position** within Word (Bits)	Description	Center Wavelength	Additional Detail
Gain & TDI	8	677			Band 1 Gain (1 = MSB, 2 = LSB) * Band 1 TDI Setting (3=MSB, 10=LSB)* Band 2 Gain Band 2 TDI Setting Band 3 Gain Band 3 TDI Setting Band 4 Gain Band 4 TDI Setting Band 5 Gain Band 5 TDI Setting Band 6 Gain Band 6 TDI Setting Band 7 Gain Band 7 TDI Setting Band 8 Gain Band 8 TDI Setting	412 nm 443 nm 490 nm 510 nm 555 nm 670 nm 765 nm 865 nm	Appendix B * MSB, LSB Definitions Identical in All 8 Bands
Imagery	10,304	685	1-8 9-16 17-10,296 10,297-10,304		<ul style="list-style-type: none"> Start Pixel Dark Restore Pixel Data Pixels (Bit 1 = MSB, Bit 10 = LSB) <ul style="list-style-type: none"> - Pixel 1 [Band 1 (10 bits), . . . Band 8 (10 bits)] ↓ - Pixel 1,285 [Band 1 (10 bits), . . . Band 8 (10 bits)] Stop Pixel <p>This imagery field is the only SeaStar L-Band field that is scrambled.</p>	Figure A-3. Table A-4.	
Pad	2	10,989	1 2		0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0		

Table A-1. L-Band Direct Downlink Format Description

Field	No. of * Words in Field	Position ** within Minor Frame (Words)	Position** within Field (Words)	Position** within Word (Bits)	Description	Additional Detail	
Auxiliary Sync	100	10,991	1 2 3 4 ↓ 99 100		1 1 1 1 1 0 0 0 1 0 1 1 1 1 1 1 0 0 1 1 0 1 1 0 1 1 0 1 0 1 1 0 1 0 1 1 1 1 0 1 ↓ 0 1 1 1 1 1 0 0 0 0 1 1 1 1 0 0 1 1 0 0	Derived from the non-inverted output of a 1023-bit PN sequence provided by a feed-back shift register generating the polynomial: $X^{10} + X^5 + X^2 + X + 1$ The generator is started in the all 1's state at the beginning of the word 10,991.	

* - Word Size is 10 bits throughout table

** - Position Definitions

Position Within Minor Frame (words)

- Gives the word position of the start of the field in the minor frame.

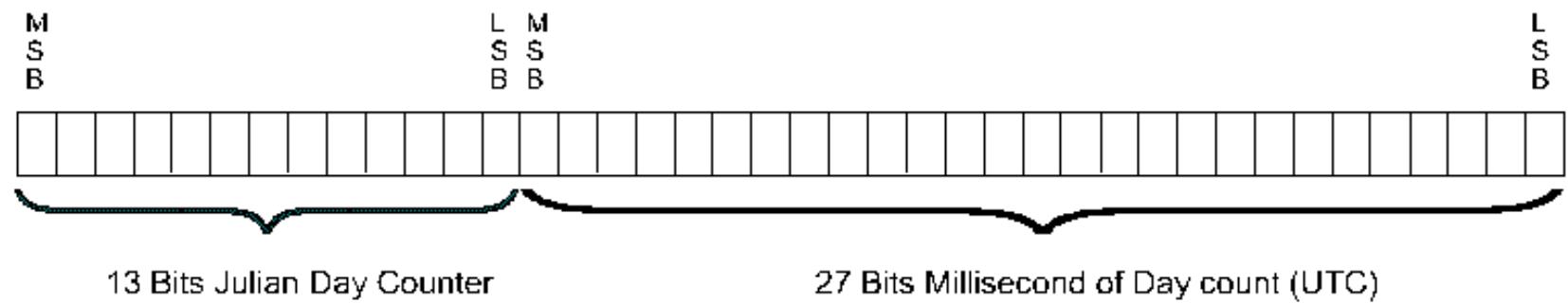
Position Within Field (words)

- Gives the word position of the parameter within the field.

Position Within Word (bits)

- Gives the position of the bit within the word identified

Figure A-2. Minor Frame Time Code Format



$2^{13} = 8192$ days = 22.43 Years
Conversion: Day Counter = Julian Date - 2449000.5

Start Date = 13 Jan 1993 at 00:00:00.0 UTC
= 2449000.5 Julian Date
= 0 Day Counter

End Date = 19 Jun 2015 at 00:00:00.0 UTC
= 2457192.5 Julian Date
= 8192 Day Counter

$2^{27} = 134,217,728$ Milliseconds
There are only 86,400,000 milliseconds/day
Counter resets to zero after 86,399,999 (midnight UTC)
and increments day counter by one

Table A-2. Spacecraft Attitude and State Vector Variables

Field	Position Within HRPT Minor Frame* (bytes)	Size	Variable Type	Variable Name	Coordinate Frame **	Units	Description ***
State-of-Health Telemetry	216-219	4 bytes	Float	Yaw_Rate	SeaStar Spacecraft Attitude Control Coordinates	deg/sec	Satellite Angular Rates
State-of-Health Telemetry	220-223	4 bytes	Float	Pitch_Rate	SeaStar Spacecraft Attitude Control Coordinates	deg/sec	
State-of-Health Telemetry	224-227	4 bytes	Float	Roll_Rate	SeaStar Spacecraft Attitude Control Coordinates	deg/sec	
State-of-Health Telemetry	252-259	8 bytes	Double	ACS_Reference_Time	N/A	sec	Time When Satellite Attitude and State Vector Data is Valid. Defined as number of seconds from 5 January 1980 midnight.
State-of-Health Telemetry	280-283	4 bytes	Float	Yaw	SeaStar Spacecraft Attitude Control Coordinates	deg	Satellite Attitude
State-of-Health Telemetry	284-287	4 bytes	Float	Pitch	SeaStar Spacecraft Attitude Control Coordinates	deg	
State-of-Health Telemetry	288-291	4 bytes	Float	Roll	SeaStar Spacecraft Attitude Control Coordinates	deg	
State-of-Health Telemetry	292-299	8 bytes	Double	X-Position	Geocentric Inertial (GCI) Coordinates	m	Satellite Orbital Position
State-of-Health Telemetry	300-307	8 bytes	Double	Y-Position	Geocentric Inertial (GCI) Coordinates	m	
State-of-Health Telemetry	308-315	8 bytes	Double	Z-Position	Geocentric Inertial (GCI) Coordinates	m	
State-of-Health Telemetry	316-323	8 bytes	Double	X_Velocity	Geocentric Inertial (GCI) Coordinates	m/sec	Satellite Orbital Velocity
State-of-Health Telemetry	324-331	8 bytes	Double	Y_Velocity	Geocentric Inertial (GCI) Coordinates	m/sec	
State-of-Health Telemetry	332-339	8 bytes	Double	Z_Velocity	Geocentric Inertial (GCI) Coordinates	m/sec	

* Counted in 8-bit bytes from the start of HRPT minor frame 1 of each major frame. This data is not repeated in minor frames two and three.

** SeaStar Spacecraft Attitude Control Coordinates
X - axis toward nominal orbit velocity vector
Y - axis such that $Z = X \times Y$ ("right hand rule")
Z - axis toward nadir
Roll - Rotation about X axis, positive for Y x Z
Pitch - Rotation about Y axis, positive for Z x X
Yaw - Rotation about Z axis, positive for X x Y
Standard Geocentric Inertial (GCI) Coordinates
X - axis toward vernal equinox
Y - axis such that $Z = X \times Y$ ("right hand rule")
Z - axis toward North celestial pole

*** Variables updated every 2.0 seconds

Table A-3. Instrument Telemetry

Word Position in HRPT Minor Frame	Word # in Inst Tlm Field	Image Data Time Tag	Notes
633	1	<ul style="list-style-type: none"> • Milliseconds since last GPS pulse • Word 1, Bit 1 = MSB • Word 4, Bit 8 = LSB 	See section 2.1.1 for a description of how to use this time tag.
634	2		
635	3		
636	4		

Word Position in HRPT Minor Frame	Word # in Inst Tlm Field	Bit #	SeaWiFS Discrete Telemetry	Value 0	Value 1	Notes
637	5	1	Pad			
"	5	2	Pad			
"	5	3	Servo A/B Selected	B	A	
"	5	4	Ang Mom Comp On	OFF	ON	7
"	5	5	Servo A Lock	LOCKED	UNLOCKED	
"	5	6	Servo B Lock	LOCKED	UNLOCKED	
"	5	7	Timing A/B Select	B	A	
"	5	8	Tilt A Selected	OFF	ON	
"	5	9	Tilt B Selected	OFF	ON	
"	5	10	Tilt Telemetry On	OFF	ON	
638	6	1	Pad			
"	6	2	Pad			
"	6	3	Stow On	OFF	ON	8
"	6	4	Stow Aligned	YES	NO	8
"	6	5	Heaters Status	DISABLED	ENABLED	
"	6	6	Solar Door Actuator Status	LATCH RELEASE POWERED	LATCH RELEASE UNPOWERED	
"	6	7	Analog Power Status	OFF	ON	
"	6	8	Tilt Platform Limit	Resolver outside normal range	Resolver inside normal range	9
"	6	9	Tilt Base Limit	Resolver outside normal range	Resolver inside normal range	9
"	6	10	Tilt Nadir (0 Deg) Aligned	Both resolvers aligned within $\pm 0.25^\circ$	Both resolvers not aligned within $\pm 0.25^\circ$	9
639	7	1	Pad			
"	7	2	Pad			
"	7	3	Tilt Aft (+20 Deg) Aligned	Both resolvers aligned within $\pm 0.25^\circ$	Both resolvers not aligned within $\pm 0.25^\circ$	9
"	7	4	Tilt Forward (-20 Deg) Aligned	Both resolvers aligned within $\pm 0.25^\circ$	Both resolvers not aligned within $\pm 0.25^\circ$	9
"	7	5	Data Mode Select	SOLAR	EARTH	
"	7	6	Half Angle Mirror Side	SIDE 1	SIDE 2	11
"	7	7	Image Data Sync Status	NO SYNC	SYNC	
"	7	8	Ang MOM Comp A at Speed	AT SPEED	NOT AT SPEED	7
"	7	9	Ang MOM Comp B at Speed	AT SPEED	NOT AT SPEED	7
"	7	10	Spare	N/A	N/A	

Table A-3. Instrument Telemetry (cont'd)

Word Position in HRPT Minor Frame	Word # in Inst Tlm Field	SeaWiFS Analog Telemetry	Units	Slope (m)	Intercept (b)	Notes
640	8	Band 1/2 FPA Temperature	deg C	-0.26670	66.66700	1, 2, 12
641	9	Band 3/4 FPA Temperature	deg C	-0.26670	66.66700	1, 2, 12
642	10	Band 5/6 FPA Temperature	deg C	-0.26670	66.66700	1, 2, 12
643	11	Band 7/8 FPA Temperature	deg C	-0.26670	66.66700	1, 2, 12
644	12	Telescope Motor Temperature	deg C	-0.26670	66.66700	1, 12
645	13	Tilt Base Temperature	deg C	-0.26670	66.66700	1, 12
646	14	Tilt Platform Temperature	deg C	-0.26670	66.66700	1, 12
647	15	Half Angle Motor Temperature	deg C	-0.26670	66.66700	1, 12
648	16	Power Supply A Input Current	A	0.02000	0.26000	12
649	17	Power Supply B Input Current	A	0.02000	0.26000	12
650	18	+15 V Analog Power Voltage	V	0.07500	0.00000	12
651	19	-15 V Analog Power Voltage	V	-0.07500	0.00000	12
652	20	+5 V Logic Power Voltage	V	0.02500	0.00000	12
653	21	Power Supply Temperature	deg C	-0.26670	66.66700	1, 12
654	22	B1/B2 Postamp Temperature	deg C	-0.26670	66.66700	1, 12
655	23	Servo Driver Temperature	deg C	-0.26670	66.66700	1, 12
656	24	+30 V Servo Power Voltage	V	0.15000	0.00000	12
657	25	+21 V Servo Power Voltage	V	0.10440	0.00000	12
658	26	-21 V Servo Power Voltage	V	-0.10440	0.00000	12
659	27	+5 V Servo Power Voltage	V	0.02500	0.00000	12
660	28	Angular Momentum Speed	RPM	8.52000	-377.00000	4, 10, 12
661	29	Tilt Platform Position	deg	1.44000	0.00000	6, 12
662	30	Tilt Base Position	deg	1.44000	0.00000	6, 12
663	31	+28 V Heater Voltage	V	0.14000	0.00000	12
664	32	Telescope A Motor Current	A	0.00240	0.00000	3, 12
665	33	Telescope B Motor Current	A	0.00240	0.00000	3, 12
666	34	Half Angle A Motor Current	A	0.00240	0.00000	3, 12
667	35	Half Angle B Motor Current	A	0.00240	0.00000	3, 12
668	36	Servo A Phase Error	mr	0.01000	-1.25000	5, 12
669	37	Servo B Phase Error	mr	0.01000	-1.25000	5, 12
670	38	Ang Mom Comp A Motor Current	A	0.01600	0.00000	3, 12
671	39	Ang Mom Comp B Motor Current	A	0.01600	0.00000	3, 12
672 - 676	40 - 44	Padding to Fill 44 Word Field	N/A	N/A	N/A	N/A

Slope - Intercept Linear Conversion: $Y = mX + b$

Y = Desired engineering value in units above

m = Slope from table above

X = Decimal equivalent of 10-bit binary word

b = Y axis intercept from table above.

Table A-3. Instrument Telemetry (cont'd)

NOTES:

1. The conversion of temperature data from raw digital counts to engineering units is a simplified linear approximation of a logarithmic function accurate to within a few deg C. for temperature ranges between 7 and 40° C. Above 40° this approximation becomes inaccurate although the SeaWiFS temperatures are not expected to reach this level. More precise temperature telemetry values may be obtained by following the process defined in Appendix D.
2. Temperature data is valid for bands 1, 3, 5 and 7 when A side cmd/tlm circuit is selected. When B side cmd/tlm circuit is selected, temperature data is valid for bands 2, 4, 6, and 8. Band 4 sensor data is not operational (sensor open after cloud channel rework).
3. Motor currents - The conversion factors in Table A-3 convert the measured telemetry voltage to a pseudo RMS current. The motor torque may be calculated for the Telescope, Half Angle and Angular Momentum motors as current x Torque constant x torque factor as follows:

Tele & HAM	<i>current x 40 x 0.707</i>
Ang Mom	<i>current x 10 x 0.5</i>

Note also that the telemetry will have some temperature dependence due to rectification diodes in the telemetry circuit.

4. Angular Momentum Speed - The resultant value represents approximately the speed of the motor but has some dependence on the electronics module temperature.
5. Servo A/B Phase Error - This telemetry was originally intended to be able to monitor changes in pointing position as the telescope is rotating. It turns out that the rotation is very smooth and the servo loop maintains speed very well so that motor current (and thus torque) is a much more sensitive measure of changes in the motor bearings and will become quite excessive before the phase error indicates a significant change.
6. The scanner tilts about the spacecraft Y axis with nadir pointing aligned with the spacecraft X axis (ref. coordinates defined at bottom of Table A-2). Tilt platform and tilt base positions should have the following values based on the scanner tilt position:

Tilt Position	Tilt Platform Position (Deg)	Tilt Base Position (Deg)
AFT (20°)	53 ± 5	225 ± 20
Nadir (0°)	215 ± 20	225 ± 20
Forward (20°)	190 ± 20	50 ± 5

7. ANG MOM Telemetry - The angular momentum A and B drives are selected when the servo A and B are selected, hence the only telemetry are the ON and AT SPEED conditions. On only indicates that the relays are in the correct position to apply power to the drive when the instrument is on. The AT SPEED telemetry is only high for about 5 seconds, the time it takes the wheel to reach about 90% of speed when power is applied to the driver.
8. STOW telemetry - The STOW ON telemetry indicates that the relays have been set up apply power to one winding of the telescope motor. The STOW ALIGNED indicates that, following a MOTOR STOP command, the telescope motor has slowed to less than 2 RPM and has reached the anti-Nadir index position; this telemetry goes inactive when the instrument is commanded off, even if STOW power is applied.
9. TILT position - The ALIGNED positions indicates that both tilt motor resolvers have reached one of the three predetermined position pairs (± 2 steps) that correspond to their "top-dead-center" locations relative to the tilt arm between them. LIMIT indicates that either resolver has exceeded minimum or maximum values.
10. When B side Ang Mom compensator is selected, slightly more accurate RPM values can be obtained by using slope = 7.92 and intercept = -28°.
11. This telemetry is not functional when the "B" side servo is selected. Use 1/2 angle mirror data in image data start and stop synch.
12. The SeaWiFS Interface Unit (SIU) uses an active clamping circuit to protect its A to D converters from any failure in the SeaWiFS analog telemetry circuits. The clamping circuit limits the range of the valid SeaWiFS analog telemetry to the values shown in Table A-3a.

TABLE A-3A. SEAWIFS ANALOG TELEMETRY VALID RANGE*

<u>U_ID</u>	<u>SU_B</u>	<u>SHORT NM</u>	<u>Linear Conversion Region</u>		<u>Units</u>
			<u>Low</u>	<u>High</u>	
7028	SWI	BAND_1_2_FPA_TEMP	6.7	60.0	DEGC
7029	SWI	BAND_3_4_FPA_TEMP	6.7	60.0	DEGC
7030	SWI	BAND_5_6_FPA_TEMP	6.7	60.0	DEGC
7031	SWI	BAND_7_8_FPA_TEMP	6.7	60.0	DEGC
7032	SWI	TELESCOPE_MOTOR_TEMP	6.7	60.0	DEGC
7033	SWI	TILT_BASE_TEMP	6.7	60.0	DEGC
7034	SWI	TILT_PLATFORM_TEMP	6.7	60.0	DEGC
7035	SWI	HALF_ANG_MIRROR_MOTOR_TEMP	6.7	60.0	DEGC
7036	SWI	PS_A_INPUT_CURRENT	0.76	4.76	AMP
7037	SWI	PS_B_INPUT_CURRENT	0.76	4.76	AMP
7038	SWI	PS_15_V_ANALOG	1.88	16.88	V
7039	SWI	PS_MINUS_15_V_ANALOG	-16.88	-1.88	V
7040	SWI	PS_5_V_LOGIC	0.63	5.63	V
7041	SWI	PS_TEMPERATURE	6.7	60.0	DEGC
7042	SWI	BAND_1_2_POSTAMP_TEMP	6.7	60.0	DEGC
7043	SWI	SERVO_DRIVER_TEMP	6.7	60.0	DEGC
7044	SWI	PS_30_V_SERVO	3.75	33.75	V
7045	SWI	PS_21_V_SERVO	2.61	23.49	V
7046	SWI	PS_MINUS_21_V_SERVO	-23.49	-2.61	V
7047	SWI	PS_5_V_SERVO	0.63	5.63	V
7048	SWI	ANG_MOM_COMP_SPEED	-164	1540	RPM
7049	SWI	TILT_PLATFORM_POSITION	36	324	Degrees
7050	SWI	TILT_BASE_POSITION	36	324	Degrees
7051	SWI	28_V_HEATER_VOLTAGE	3.50	31.50	VOLT
7052	SWI	TELESCOPE_A_MOTOR_CURRENT	0.06	0.54	AMP
7053	SWI	TELESCOPE_B_MOTOR_CURRENT	0.06	0.54	AMP
7054	SWI	HALF_ANG_MIR_A_MOTOR_CURR	0.06	0.54	AMP
7055	SWI	HALF_ANG_MIR_B_MOTOR_CURR	0.06	0.54	AMP
7056	SWI	SERVO_A_PHASE_ERROR	-1.0	1.0	mr
7057	SWI	SERVO_B_PHASE_ERROR	-1.0	1.0	mr
7058	SWI	ANG_MOM_COMP_A_MOTOR_CURR	0.40	3.60	AMP
7059	SWI	ANG_MOM_COMP_B_MOTOR_CURR	0.40	3.60	AMP

* Reference note 12 on Table A-3.

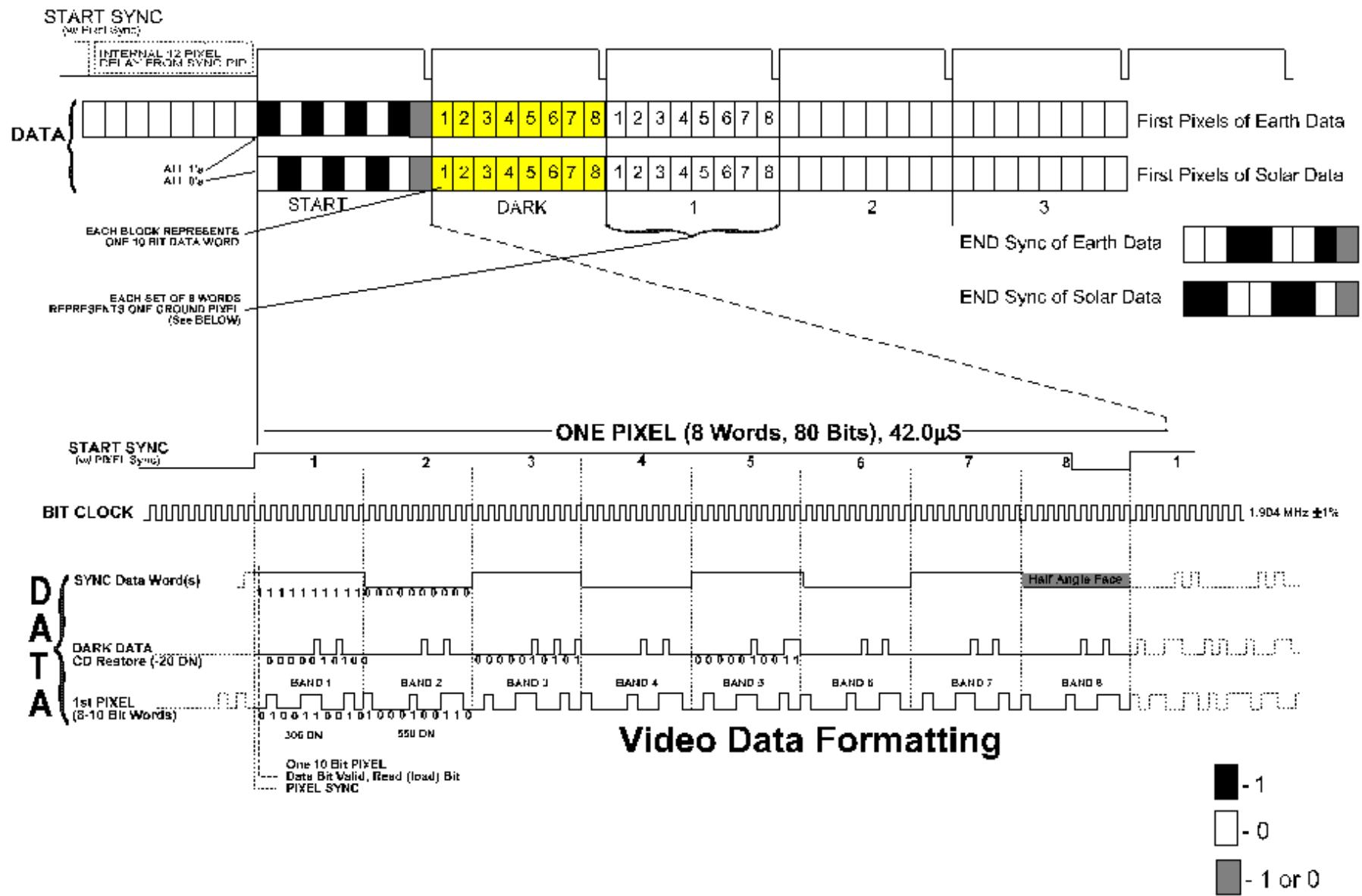


Figure A-3. Imagery Field Definition

Table A-4. Imagery Field Auxiliary Information

Sensor Mode	Half-Angle Mirror Side	Start Pixel *	Stop Pixel *
Earth	Even	1 0 1 0 1 0 1 0	1 1 0 0 1 1 0 0
Earth	Odd	1 0 1 0 1 0 1 1	1 1 0 0 1 1 0 1
Solar	Even	0 1 0 1 0 1 0 0	0 0 1 1 0 0 1 0
Solar	Odd	0 1 0 1 0 1 0 1	0 0 1 1 0 0 1 1

“Start” and “Stop” Pixels

Start and stop pixels have a fixed bit pattern that changes for every even and odd scan line and changes for the Spacecraft mode. The half-angle mirror has two sides with (possibly) different reflective properties and may require two different sets of calibration coefficients for even and odd scan lines. Both the instrument telemetry field and start/stop pixel can be used to identify which side of the half-angle mirror was used for that particular line. NOTE: *The half angle mirror telemetry is not functional on the redundant side of SeaWiFS electronics, so the start and stop pixels are the better source to use.* The start and stop pixel also indicates if the sensor is in nominal imaging mode (Earth mode) or solar calibration mode (Solar mode). For purposes of the L-band imagery downlink, the sensor will be in the Earth mode.

* Each digit in the table represents a 10-bit number equal to the single bit value in the table (number 1 in the table means 1111111111 in the data stream, number 0 in the table means 0000000000 in the data stream). For example, for the Earth mode and for the even side of half-angle mirror, the value of an equivalent position of the spectral band 1 for the start pixel is all ones (10 bits) and the spectral band 2 has all zeros (also 10 bits). The last 10 bits of the start and stop pixels indicate the half angle mirror side (all 0's = even side; all 1's = odd side). This is illustrated in Figure A-3.

“Dark” Pixel

The instrument used a Dark Current (DC) restore technique to eliminate electronic offsets from the data. The DC restore is performed during the part of the scan where the telescope is looking into the housing and the aperture is blocked. The signal is captured during this time and used as the reference during the earth viewing portion of the scan. The digital value of the signal during DC restore is returned in the data stream as pixel zero. It has a typical Digital Number (DN) value around 20. Every value reported by the instrument has the offset for that band and TDI choice included in it. In order to arrive at the actual DN value for every pixel in the data stream, the value of the dark current pixel must be subtracted from every image data pixel in the scan line.

APPENDIX B
SEAWIFS GAIN & TDI TELEMETRY

The telemetry format for SeaWiFS Gains and TDI is identical to the Serial Command data format sent to the instrument from the spacecraft. It consists of 80 bits which can be separated into 8 groups of 10 bits. Each group contains two Gain and eight TDI control bits for one band. The Gain bits are decoded as follows:

00 = GAIN 1, 01 = GAIN 2, 10 = GAIN 3 and 11 = GAIN 4.

Table B-1 lists the measured 4:1 TDI Science maximum scene radiance input in GAIN 1, the fixed gain Cloud radiance input and the Gain 2, 3 and 4 ratios for each spectral band relative to GAIN 1. Bands 1, 3, 5 and 7 use detector 1 for cloud channel while bands 2, 4, 6 and 8 use detector 4. Gain ratios apply only when the cloud channel is included with a weight of one (see next paragraph).

Table B-1. Science and Cloud Channel Maximum Radiance Inputs & Gain Ratios

Maximum Scene Radiance Input		GAIN RATIOS (relative to GAIN 1)		
STATE: BAND	GAIN 1 SCIENCE	GAIN CLOUD	GAIN 2 ratio	GAIN 3 ratio
1	10.899	60.159	1.931	1.302
2	10.555	67.908	1.940	1.303
3	8.179	68.212	1.951	0.899
4	7.161	66.466	1.955	0.796
5	5.742	64.971	1.961	0.652
6	3.247	54.926	1.970	0.376
7	2.289	42.978	1.970	0.323
8	1.639	34.379	1.970	0.272

mW/cm²-sr-μm

Measured for 4:1 TDI

The remaining 8 bits control the Time Delay and Integration (TDI) configuration for the band. Each band has four detector elements each of which is digitized and delayed so that samples of the same pixel on the ground can be added together. Adding the four detector samples is called 4:1 TDI. However, if one detector or its preamp circuit or A/D becomes noisy or fails, the bad channel can be ignored by selecting a TDI code that implements a 3:1 (or 2:1 or 1:1) mode that does not include the bad channel. The TDI “weighting” is always four (4); that is, the simple discrete logic circuit always adds four numbers which means that one of the detector samples gets added more than one when TDI combinations other than 4:1 are selected. 1:1 TDI is implemented by adding the same number four times.

Tables B-2 and B-3 list the TDI codes in decimal binary and decodes them as to which detector elements are added and how many times. Table B-2 lists them in decimal equivalent number order and Table B-3 lists them in TDI order starting with 1:1 TDI. There are a total of 256 codes. Codes are listed in binary form in the column labeled “BAND X TDI.” The columns labeled “DETECTOR SELECTIONS” indicate the number of times each detector is added which is summarized as to detectors used and N:1 TDI. The addition algorithm is also shown as an equation in the column labeled “COMBINATION SELECTED.”

Because of the cloud channel change, the gain ratios will change if the relative weight of the cloud channel is other than one. An obvious example is when 1:1 TDI is selected; for non-cloud channels the GAIN 1 radiometric gain goes up about 30% because the cloud channel is excluded and the gain ratios change slightly. If a TDI mode includes the cloud channel more than once, then the radiometric gain decreases and the gain ratios are reduced. The ratios can be calculated from the data given; they are different for each band because the ratio between cloud and non-cloud postamp gains are different for each band.

Table B-2. SeaWiFS TDI Telemetry List Sorted by Decimal Equivalent

DEC #	BAND "X" TDI BIT								DETECTOR SELECTION					N:1 TDI	COMBINATION SELECTED
	1	2	3	4	5	6	7	8	1	2	3	4	DET		
0	0	0	0	0	0	0	0	0	1	1	1	1	1234	4	Det1 + Det2 + Det3 + Det4
1	0	0	0	0	0	0	0	1	1	0	1	2	134	3	Det1 + Det3 + 2*Det4
2	0	0	0	0	0	0	1	0	1	0	2	1	124	3	Det1 + 2*Det3 + Det4
3	0	0	0	0	0	0	1	1	1	0	1	2	134	3	Det1 + Det3 + 2*Det4
4	0	0	0	0	0	1	0	0	2	1	0	1	124	3	2*Det1 + Det2 + Det4
5	0	0	0	0	0	1	0	1	2	0	0	2	14	2	2*Det1 + 2*Det4
6	0	0	0	0	0	1	1	0	2	0	1	1	134	3	2*Det1 + Det3 + Det4
7	0	0	0	0	0	1	1	1	2	0	0	2	14	2	2*Det1 + 2*Det4
8	0	0	0	0	1	0	0	0	1	2	0	1	124	3	Det1 + 2*Det2 + Det4
9	0	0	0	0	1	0	0	1	1	1	0	2	124	3	Det1 + Det2 + 2*Det4
10	0	0	0	0	1	0	1	0	1	1	1	1	1234	4	Det1 + Det2 + Det3 + Det4
11	0	0	0	0	1	0	1	1	1	1	0	2	124	3	Det1 + Det2 + 2*Det4
12	0	0	0	0	1	1	0	0	2	1	0	1	124	3	2*Det1 + Det2 + Det4
13	0	0	0	0	1	1	0	1	2	0	0	2	14	2	2*Det1 + 2*Det4
14	0	0	0	0	1	1	1	0	2	0	1	1	134	3	2*Det1 + Det3 + Det4
15	0	0	0	0	1	1	1	1	2	0	0	2	14	2	2*Det1 + 2*Det4
16	0	0	0	1	0	0	0	0	1	2	1	0	123	3	Det1 + 2*Det2 + Det3
17	0	0	0	1	0	0	0	1	1	1	1	1	1234	4	Det1 + Det2 + Det3 + Det4
18	0	0	0	1	0	0	1	0	1	0	3	0	13	2	Det1 + 3*Det3
19	0	0	0	1	0	0	1	1	1	0	2	1	134	3	Det1 + 2*Det3 + Det4
20	0	0	0	1	0	1	0	0	2	2	0	0	12	2	2*Det1 + 2*Det2
21	0	0	0	1	0	1	0	1	2	1	0	1	124	3	2*Det1 + Det2 + Det4
22	0	0	0	1	0	1	1	0	2	0	2	0	13	2	2*Det1 + 2*Det3
23	0	0	0	1	0	1	1	1	2	0	1	1	134	3	2*Det1 + Det3 + Det4
24	0	0	0	1	1	0	0	0	1	3	0	0	12	2	Det1 + 3*Det2
25	0	0	0	1	1	0	0	1	1	2	0	1	124	3	Det1 + 2*Det2 + Det4
26	0	0	0	1	1	0	1	0	1	1	2	0	123	3	Det1 + Det2 + 2*Det3
27	0	0	0	1	1	0	1	1	1	1	1	1	1234	4	Det1 + Det2 + Det3 + Det4
28	0	0	0	1	1	1	0	0	2	2	0	0	12	2	2*Det1 + 2*Det2
29	0	0	0	1	1	1	0	1	2	1	0	1	124	3	2*Det1 + Det2 + Det4
30	0	0	0	1	1	1	1	0	2	0	2	0	13	2	2*Det1 + 2*Det3
31	0	0	0	1	1	1	1	1	2	0	1	1	134	3	2*Det1 + Det3 + Det4
32	0	0	1	0	0	0	0	0	2	1	1	0	123	3	2*Det1 + Det2 + Det3
33	0	0	1	0	0	0	0	1	3	0	1	0	13	2	3*Det1 + Det3
34	0	0	1	0	0	0	1	0	2	0	2	0	13	2	2*Det1 + 2*Det3
35	0	0	1	0	0	0	1	1	3	0	1	0	13	2	3*Det1 + Det3
36	0	0	1	0	0	1	0	0	3	1	0	0	12	2	3*Det1 + Det2
37	0	0	1	0	0	1	0	1	4	0	0	0	1	1	4*Det1
38	0	0	1	0	0	1	1	0	3	0	1	0	13	2	3*Det1 + Det3
39	0	0	1	0	0	1	1	1	4	0	0	0	1	1	4*Det1
40	0	0	1	0	1	0	0	0	2	2	0	0	12	2	2*Det1 + 2*Det2
41	0	0	1	0	1	0	0	1	3	1	0	0	12	2	3*Det1 + Det2
42	0	0	1	0	1	0	1	0	2	1	1	0	123	3	2*Det1 + Det2 + Det3
43	0	0	1	0	1	0	1	1	3	1	0	0	12	2	3*Det1 + Det2
44	0	0	1	0	1	1	0	0	3	1	0	0	12	2	3*Det1 + Det2
45	0	0	1	0	1	1	0	1	4	0	0	0	1	1	4*Det1
46	0	0	1	0	1	1	1	0	3	0	1	0	13	2	3*Det1 + Det3
47	0	0	1	0	1	1	1	1	4	0	0	0	1	1	4*Det1

**Table B-2. SeaWiFS TDI Telemetry List Sorted By Decimal Equivalent
(cont'd)**

DEC #	BAND "X" TDI BIT								DETECTOR SELECTION				N:1 TDI	COMBINATION SELECTED	
	1	2	3	4	5	6	7	8	1	2	3	4	DET		
48	0	0	1	1	0	0	0	0	1	2	1	0	123	3	Det1 + 2*Det2 + Det3
49	0	0	1	1	0	0	0	1	2	1	1	0	123	3	2*Det1 + Det2 + Det3
50	0	0	1	1	0	0	1	0	1	0	3	0	13	2	Det1 + 3*Det3
51	0	0	1	1	0	0	1	1	2	0	2	0	13	2	2*Det1 + 2*Det3
52	0	0	1	1	0	1	0	0	2	2	0	0	12	2	2*Det1 + 2*Det2
53	0	0	1	1	0	1	0	1	3	1	0	0	12	2	3*Det1 + Det2
54	0	0	1	1	0	1	1	0	2	0	2	0	13	2	2*Det1 + 2*Det3
55	0	0	1	1	0	1	1	1	3	0	1	0	13	2	3*Det1 + Det3
56	0	0	1	1	1	0	0	0	1	3	0	0	12	2	Det1 + 3*Det2
57	0	0	1	1	1	0	0	1	2	2	0	0	12	2	2*Det1 + 2*Det2
58	0	0	1	1	1	0	1	0	1	1	2	0	123	3	Det1 + Det2 + 2*Det3
59	0	0	1	1	1	0	1	1	2	1	1	0	123	3	2*Det1 + Det2 + Det3
60	0	0	1	1	1	1	0	0	2	2	0	0	12	2	2*Det1 + 2*Det2
61	0	0	1	1	1	1	0	1	3	1	0	0	12	2	3*Det1 + Det2
62	0	0	1	1	1	1	1	0	2	0	2	0	13	2	2*Det1 + 2*Det3
63	0	0	1	1	1	1	1	1	3	0	1	0	13	2	3*Det1 + Det3
64	0	1	0	0	0	0	0	0	0	1	2	1	234	3	Det2 + 2*Det3 + Det4
65	0	1	0	0	0	0	0	1	0	0	2	2	34	2	2*Det3 + 2*Det4
66	0	1	0	0	0	0	1	0	0	0	3	1	34	2	3*Det3 + Det4
67	0	1	0	0	0	0	1	1	0	0	2	2	34	2	2*Det3 + 2*Det4
68	0	1	0	0	0	1	0	0	1	1	1	1	1234	4	Det1 + Det2 + Det3 + Det4
69	0	1	0	0	0	1	0	1	1	0	1	2	134	3	Det1 + Det3 + 2*Det4
70	0	1	0	0	0	1	1	0	1	0	2	1	134	3	Det1 + 2*Det3 + Det4
71	0	1	0	0	0	1	1	1	1	0	1	2	134	3	Det1 + Det3 + 2*Det4
72	0	1	0	0	1	0	0	0	0	3	0	1	24	2	3*Det2 + Det4
73	0	1	0	0	1	0	0	1	0	2	0	2	24	2	2*Det2 + 2*Det4
74	0	1	0	0	1	0	1	0	0	2	1	1	234	3	2*Det2 + Det3 + Det4
75	0	1	0	0	1	0	1	1	0	2	0	2	24	2	2*Det2 + 2*Det4
76	0	1	0	0	1	1	0	0	1	2	0	1	124	3	Det1 + 2*Det2 + Det4
77	0	1	0	0	1	1	0	1	1	1	0	2	124	3	Det1 + Det2 + 2*Det4
78	0	1	0	0	1	1	1	0	1	1	1	1	1234	4	Det1 + Det2 + Det3 + Det4
79	0	1	0	0	1	1	1	1	1	1	0	2	124	3	Det1 + Det2 + 2*Det4
80	0	1	0	1	0	0	0	0	0	2	2	0	23	2	2*Det2 + 2*Det3
81	0	1	0	1	0	0	0	1	0	1	2	1	234	3	Det2 + 2*Det3 + Det4
82	0	1	0	1	0	0	1	0	0	0	4	0	3	1	4*Det3
83	0	1	0	1	0	0	1	1	0	0	3	1	34	2	3*Det3 + Det4
84	0	1	0	1	0	1	0	0	1	2	1	0	123	3	Det1 + 2*Det2 + Det3
85	0	1	0	1	0	1	0	1	1	1	1	1	1234	4	Det1 + Det2 + Det3 + Det4
86	0	1	0	1	0	1	1	0	1	0	3	0	13	2	Det1 + 3*Det3
87	0	1	0	1	0	1	1	1	1	0	2	1	134	3	Det1 + 2*Det3 + Det4
88	0	1	0	1	1	0	0	0	0	4	0	0	2	1	4*Det2
89	0	1	0	1	1	0	0	1	0	3	0	1	24	2	3*Det2 + Det4
90	0	1	0	1	1	0	1	0	0	2	2	0	23	2	2*Det2 + 2*Det3
91	0	1	0	1	1	0	1	1	0	2	1	1	234	3	2*Det2 + Det3 + Det4
92	0	1	0	1	1	1	0	0	1	3	0	0	12	2	Det1 + 3*Det2
93	0	1	0	1	1	1	0	1	1	2	0	1	124	3	Det1 + 2*Det2 + Det4
94	0	1	0	1	1	1	1	0	1	1	2	0	123	3	Det1 + Det2 + 2*Det3
95	0	1	0	1	1	1	1	1	1	1	1	1	1234	4	Det1 + Det2 + Det3 + Det4

**Table B-2: SeaWiFS TDI Telemetry List Sorted By Decimal Equivalent
(cont'd)**

DEC #	BAND X TDI BIT								DETECTOR SELECTION					N:1 TDI	COMBINATION SELECTED
	1	2	3	4	5	6	7	8	1	2	3	4	DET		
96	0	1	1	0	0	0	0	0	1	1	2	0	123	3	Det1 + Det2 + 2*Det3
97	0	1	1	0	0	0	0	1	2	0	2	0	13	2	2*Det1 + 2*Det3
98	0	1	1	0	0	0	1	0	1	0	3	0	13	2	Det1 + 3*Det3
99	0	1	1	0	0	0	1	1	2	0	2	0	13	2	2*Det1 + 2*Det3
100	0	1	1	0	0	1	0	0	2	1	1	0	123	3	2*Det1 + Det2 + Det3
101	0	1	1	0	0	1	0	1	3	0	1	0	13	2	3*Det1 + Det3
102	0	1	1	0	0	1	1	0	2	0	2	0	13	2	2*Det1 + 2*Det3
103	0	1	1	0	0	1	1	1	3	0	1	0	13	2	3*Det1 + Det3
104	0	1	1	0	1	0	0	0	1	3	0	0	12	2	Det1 + 3*Det2
105	0	1	1	0	1	0	0	1	2	2	0	0	12	2	2*Det1 + 2*Det2
106	0	1	1	0	1	0	1	0	1	2	1	0	123	3	Det1 + 2*Det2 + Det3
107	0	1	1	0	1	0	1	1	2	2	0	0	12	2	2*Det1 + 2*Det2
108	0	1	1	0	1	1	0	0	2	2	0	0	12	2	2*Det1 + 2*Det2
109	0	1	1	0	1	1	0	1	3	1	0	0	12	2	3*Det1 + Det2
110	0	1	1	0	1	1	1	0	2	1	1	0	123	3	2*Det1 + Det2 + Det3
111	0	1	1	0	1	1	1	1	3	1	0	0	12	2	3*Det1 + Det2
112	0	1	1	1	0	0	0	0	0	2	2	0	23	2	2*Det2 + 2*Det3
113	0	1	1	1	0	0	0	1	1	1	2	0	123	3	Det1 + Det2 + 2*Det3
114	0	1	1	1	0	0	1	0	0	0	4	0	3	1	4*Det3
115	0	1	1	1	0	0	1	1	1	0	3	0	13	2	Det1 + 3*Det3
116	0	1	1	1	0	1	0	0	1	2	1	0	123	3	Det1 + 2*Det2 + Det3
117	0	1	1	1	0	1	0	1	2	1	1	0	123	3	2*Det1 + Det2 + Det3
118	0	1	1	1	0	1	1	0	1	0	3	0	13	2	Det1 + 3*Det3
119	0	1	1	1	0	1	1	1	2	0	2	0	13	2	2*Det1 + 2*Det3
120	0	1	1	1	1	0	0	0	0	4	0	0	2	1	4*Det2
121	0	1	1	1	1	0	0	1	1	3	0	0	12	2	Det1 + 3*Det2
122	0	1	1	1	1	0	1	0	0	2	2	0	23	2	2*Det2 + 2*Det3
123	0	1	1	1	1	0	1	1	1	2	1	0	123	3	Det1 + 2*Det2 + Det3
124	0	1	1	1	1	1	0	0	1	3	0	0	12	2	Det1 + 3*Det2
125	0	1	1	1	1	1	0	1	2	2	0	0	12	2	2*Det1 + 2*Det2
126	0	1	1	1	1	1	1	0	1	1	2	0	123	3	Det1 + Det2 + 2*Det3
127	0	1	1	1	1	1	1	1	2	1	1	0	123	3	2*Det1 + Det2 + Det3
128	1	0	0	0	0	0	0	0	0	1	1	2	234	3	Det2 + Det3 + 2*Det4
129	1	0	0	0	0	0	0	1	0	0	1	3	34	2	Det3 + 3*Det4
130	1	0	0	0	0	0	0	1	0	0	2	2	34	2	2*Det3 + 2*Det4
131	1	0	0	0	0	0	1	1	0	0	1	3	34	2	Det3 + 3*Det4
132	1	0	0	0	0	1	0	0	0	1	0	3	24	2	Det2 + 3*Det4
133	1	0	0	0	0	1	0	1	0	0	0	4	4	1	4*Det4
134	1	0	0	0	0	1	1	0	0	0	1	3	34	2	Det3 + 3*Det4
135	1	0	0	0	0	1	1	1	0	0	0	4	4	1	4*Det4
136	1	0	0	0	1	0	0	0	0	2	0	2	24	2	2*Det2 + 2*Det4
137	1	0	0	0	1	0	0	1	0	1	0	3	24	2	Det2 + 3*Det4
138	1	0	0	0	1	0	1	0	0	1	1	2	234	3	Det2 + Det3 + 2*Det4
139	1	0	0	0	1	0	1	1	0	1	0	3	24	2	Det2 + 3*Det4
140	1	0	0	0	1	1	0	0	0	1	0	3	24	2	Det2 + 3*Det4
141	1	0	0	0	1	1	0	1	0	0	0	4	4	1	4*Det4
142	1	0	0	0	1	1	1	0	0	0	1	3	34	2	Det3 + 3*Det4
143	1	0	0	0	1	1	1	1	0	0	0	4	4	1	4*Det4

**Table B-2: SeaWiFS TDI Telemetry List Sorted By Decimal Equivalent
(cont'd)**

DEC #	BAND X TDI BIT								DETECTOR SELECTION					N:1 TDI	COMBINATION SELECTED
	1	2	3	4	5	6	7	8	1	2	3	4	DET		
144	1	0	0	1	0	0	0	0	0	2	1	1	234	3	2*Det2 + Det3 + Det4
145	1	0	0	1	0	0	0	1	0	1	1	2	234	3	Det2 + Det3 + 2*Det4
146	1	0	0	1	0	0	1	0	0	0	3	1	34	2	3*Det3 + Det4
147	1	0	0	1	0	0	1	1	0	0	2	2	34	2	2*Det3 + 2*Det4
148	1	0	0	1	0	1	0	0	0	2	0	2	24	2	2*Det2 + 2*Det4
149	1	0	0	1	0	1	0	1	0	1	0	3	24	2	Det2 + 3*Det4
150	1	0	0	1	0	1	1	0	0	0	2	2	34	2	2*Det3 + 2*Det4
151	1	0	0	1	0	1	1	1	0	0	1	3	34	2	Det3 + 3*Det4
152	1	0	0	1	1	0	0	0	0	3	0	1	24	2	3*Det2 + Det4
153	1	0	0	1	1	0	0	1	0	2	0	2	24	2	2*Det2 + 2*Det4
154	1	0	0	1	1	0	1	0	0	1	2	1	234	3	Det2 + 2*Det3 + Det4
155	1	0	0	1	1	0	1	1	0	1	1	2	234	3	Det2 + Det3 + 2*Det4
156	1	0	0	1	1	1	0	0	0	2	0	2	24	2	2*Det2 + 2*Det4
157	1	0	0	1	1	1	0	1	0	1	0	3	24	2	Det2 + 3*Det4
158	1	0	0	1	1	1	1	0	0	0	2	2	34	2	2*Det3 + 2*Det4
159	1	0	0	1	1	1	1	1	0	0	1	3	34	2	Det3 + 3*Det4
160	1	0	1	0	0	0	0	0	1	1	1	1	1234	4	Det1 + Det2 + Det3 + Det4
161	1	0	1	0	0	0	0	1	2	0	1	1	134	3	2*Det1 + Det3 + Det4
162	1	0	1	0	0	0	1	0	1	0	2	1	134	3	Det1 + 2*Det3 + Det4
163	1	0	1	0	0	0	1	1	2	0	1	1	134	3	2*Det1 + Det3 + Det4
164	1	0	1	0	0	1	0	0	1	1	0	2	124	3	Det1 + Det2 + 2*Det4
165	1	0	1	0	0	1	0	1	2	0	0	2	14	2	2*Det1 + 2*Det4
166	1	0	1	0	0	1	1	0	1	0	1	2	134	3	Det1 + Det3 + 2*Det4
167	1	0	1	0	0	1	1	1	2	0	0	2	14	2	2*Det1 + 2*Det4
168	1	0	1	0	1	0	0	0	1	2	0	1	124	3	Det1 + 2*Det2 + Det4
169	1	0	1	0	1	0	0	1	2	1	0	1	124	3	2*Det1 + Det2 + Det4
170	1	0	1	0	1	0	1	0	1	1	1	1	1234	4	Det1 + Det2 + Det3 + Det4
171	1	0	1	0	1	0	1	1	2	1	0	1	124	3	2*Det1 + Det2 + Det4
172	1	0	1	0	1	1	0	0	1	1	0	2	124	3	Det1 + Det2 + 2*Det4
173	1	0	1	0	1	1	0	1	2	0	0	2	14	2	2*Det1 + 2*Det4
174	1	0	1	0	1	1	1	0	1	0	1	2	134	3	Det1 + Det3 + 2*Det4
175	1	0	1	0	1	1	1	1	2	0	0	2	14	2	2*Det1 + 2*Det4
176	1	0	1	1	0	0	0	0	0	2	1	1	1234	3	2*Det2 + Det3 + Det4
177	1	0	1	1	0	0	0	1	1	1	1	1	1234	4	Det1 + Det2 + Det3 + Det4
178	1	0	1	1	0	0	1	0	0	0	3	1	34	2	3*Det3 + Det4
179	1	0	1	1	0	0	1	1	1	0	2	1	134	3	Det1 + 2*Det3 + Det4
180	1	0	1	1	0	1	0	0	0	2	0	2	24	2	2*Det2 + 2*Det4
181	1	0	1	1	0	1	0	1	1	1	0	2	124	3	Det1 + Det2 + 2*Det4
182	1	0	1	1	0	1	1	0	0	0	2	2	34	2	2*Det3 + 2*Det4
183	1	0	1	1	0	1	1	1	1	0	1	2	134	3	Det1 + Det3 + 2*Det4
184	1	0	1	1	1	0	0	0	0	3	0	1	24	2	3*Det2 + Det4
185	1	0	1	1	1	0	0	1	1	2	0	1	124	3	Det1 + 2*Det2 + Det4
186	1	0	1	1	1	0	1	0	0	1	2	1	234	3	Det2 + 2*Det3 + Det4
187	1	0	1	1	1	0	1	1	1	1	1	1	1234	4	Det1 + Det2 + Det3 + Det4
188	1	0	1	1	1	1	0	0	0	2	0	2	24	2	2*Det2 + 2*Det4
189	1	0	1	1	1	1	0	1	1	1	0	2	124	3	Det1 + Det2 + 2*Det4
190	1	0	1	1	1	1	1	0	0	0	2	2	34	2	2*Det3 + 2*Det4
191	1	0	1	1	1	1	1	1	1	0	1	2	134	3	Det1 + Det3 + 2*Det4

**Table B-2. SeaWiFS TDI Telemetry List Sorted By Decimal Equivalent
(cont'd)**

DEC #	BAND X TDI BIT								DETECTOR SELECTION					N:1 TDI	COMBINATION SELECTED
	1	2	3	4	5	6	7	8	1	2	3	4	DET		
192	1	1	0	0	0	0	0	0	0	1	2	1	234	3	Det2 + 2*Det3 + Det4
193	1	1	0	0	0	0	0	1	0	0	2	2	34	2	2*Det3 + 2*Det4
194	1	1	0	0	0	0	1	0	0	0	3	1	34	2	3*Det3 + Det4
195	1	1	0	0	0	0	1	1	0	0	2	2	34	2	2*Det3 + 2*Det4
196	1	1	0	0	0	1	0	0	0	1	1	2	234	3	Det2 + Det3 + 2*Det4
197	1	1	0	0	0	1	0	1	0	0	1	3	34	2	Det3 + 3*Det4
198	1	1	0	0	0	1	1	0	0	0	2	2	34	2	2*Det3 + 2*Det4
199	1	1	0	0	0	1	1	1	0	0	1	3	34	2	Det3 + 3*Det4
200	1	1	0	0	1	0	0	0	0	3	0	1	24	2	3*Det2 + Det4
201	1	1	0	0	1	0	0	1	0	2	0	2	24	2	2*Det2 + 2*Det4
202	1	1	0	0	1	0	1	0	0	2	1	1	234	3	2*Det2 + Det3 + Det4
203	1	1	0	0	1	0	1	1	0	2	0	2	24	2	2*Det2 + 2*Det4
204	1	1	0	0	1	1	0	0	0	2	0	2	24	2	2*Det2 + 2*Det4
205	1	1	0	0	1	1	0	1	0	1	0	3	24	2	Det2 + 3*Det4
206	1	1	0	0	1	1	1	0	0	1	1	2	234	3	Det2 + Det3 + 2*Det4
207	1	1	0	0	1	1	1	1	0	1	0	3	24	2	Det2 + 3*Det4
208	1	1	0	1	0	0	0	0	0	2	2	0	23	2	2*Det2 + 2*Det3
209	1	1	0	1	0	0	0	1	0	1	2	1	234	3	Det2 + 2*Det3 + Det4
210	1	1	0	1	0	0	1	0	0	0	4	0	3	1	4*Det3
211	1	1	0	1	0	0	1	1	0	0	3	1	34	2	3*Det3 + Det4
212	1	1	0	1	0	1	0	0	0	2	1	1	234	3	2*Det2 + Det3 + Det4
213	1	1	0	1	0	1	0	1	0	1	1	2	234	3	Det2 + Det3 + 2*Det4
214	1	1	0	1	0	1	1	0	0	0	3	1	34	2	3*Det3 + Det4
215	1	1	0	1	0	1	1	1	0	0	2	2	34	2	2*Det3 + 2*Det4
216	1	1	0	1	1	0	0	0	0	4	0	0	2	1	4*Det2
217	1	1	0	1	1	0	0	1	0	3	0	1	24	2	3*Det2 + Det4
218	1	1	0	1	1	0	1	0	0	2	2	0	23	2	2*Det2 + 2*Det3
219	1	1	0	1	1	0	1	1	0	2	1	1	234	3	2*Det2 + Det3 + Det4
220	1	1	0	1	1	1	0	0	0	3	0	1	24	2	3*Det2 + Det4
221	1	1	0	1	1	1	0	1	0	2	0	2	24	2	2*Det2 + 2*Det4
222	1	1	0	1	1	1	1	0	0	1	2	1	234	3	Det2 + 2*Det3 + Det4
223	1	1	0	1	1	1	1	1	0	1	1	2	234	3	Det2 + Det3 + 2*Det4
224	1	1	1	0	0	0	0	0	1	1	2	0	123	3	Det1 + Det2 + 2*Det3
225	1	1	1	0	0	0	0	1	2	0	2	0	13	2	2*Det1 + 2*Det3
226	1	1	1	0	0	0	1	0	1	0	3	0	13	2	Det1 + 3*Det3
227	1	1	1	0	0	0	1	1	2	0	2	0	13	2	2*Det1 + 2*Det3
228	1	1	1	0	0	1	0	0	1	1	1	1	1234	4	Det1 + Det2 + Det3 + Det4
229	1	1	1	0	0	1	0	1	2	0	1	1	134	3	2*Det1 + Det3 + Det4
230	1	1	1	0	0	1	1	0	1	0	2	1	134	3	Det1 + 2*Det3 + Det4
231	1	1	1	0	0	1	1	1	2	0	1	1	134	3	2*Det1 + Det3 + Det4
232	1	1	1	0	1	0	0	0	1	3	0	0	12	2	Det1 + 3*Det2
233	1	1	1	0	1	0	0	1	2	2	0	0	12	2	2*Det1 + 2*Det2
234	1	1	1	0	1	0	1	0	1	2	1	0	123	3	Det1 + 2*Det2 + Det3
235	1	1	1	0	1	0	1	1	2	2	0	0	12	2	2*Det1 + 2*Det2
236	1	1	1	0	1	1	0	0	1	2	0	1	124	3	Det1 + 2*Det2 + Det4
237	1	1	1	0	1	1	0	1	2	1	0	1	124	3	2*Det1 + Det2 + Det4
238	1	1	1	0	1	1	1	0	1	1	1	1	1234	4	Det1 + Det2 + Det3 + Det4
239	1	1	1	0	1	1	1	1	2	1	0	1	124	3	2*Det1 + Det2 + Det4

**Table B-2: SeaWiFS TDI Telemetry List Sorted By Decimal Equivalent
(cont'd)**

DEC #	BAND X TDI BIT								DETECTOR SELECTION					N:1 TDI	COMBINATION SELECTED
	1	2	3	4	5	6	7	8	1	2	3	4	DET		
240	1	1	1	1	0	0	0	0	0	2	2	0	23	2	2*Det2 + 2*Det3
241	1	1	1	1	0	0	0	1	1	1	2	0	123	3	Det1 + Det2 + 2*Det3
242	1	1	1	1	0	0	1	0	0	0	4	0	3	1	4*Det3
243	1	1	1	1	0	0	1	1	1	0	3	0	13	2	Det1 + 3*Det3
244	1	1	1	1	0	1	0	0	0	2	1	1	234	3	2*Det2 + Det3 + Det4
245	1	1	1	1	0	1	0	1	1	1	1	1	1234	4	Det1 + Det2 + Det3 + Det4
246	1	1	1	1	0	1	1	0	0	0	3	1	34	2	3*Det3 + Det4
247	1	1	1	1	0	1	1	1	1	0	2	1	134	3	Det1 + 2*Det3 + Det4
248	1	1	1	1	1	0	0	0	0	4	0	0	2	1	4*Det2
249	1	1	1	1	1	0	0	1	0	3	0	1	24	2	3*Det2 + Det4
250	1	1	1	1	1	0	1	0	0	2	2	0	23	2	2*Det2 + 2*Det3
251	1	1	1	1	1	0	1	1	1	2	1	0	123	3	Det1 + 2*Det2 + Det3
252	1	1	1	1	1	1	0	0	0	3	0	1	24	2	3*Det2 + Det4
253	1	1	1	1	1	1	0	1	1	2	0	1	124	3	Det1 + 2*Det2 + Det4
254	1	1	1	1	1	1	1	0	0	1	2	1	234	3	Det2 + 2*Det3 + Det4
255	1	1	1	1	1	1	1	1	1	1	1	1	1234	4	Det1 + Det2 + Det3 + Det4

Table B-3: SeaWiFS TDI Telemetry List Sorted By TDI Level and Combination

DEC #	BAND X TDI BIT								DETECTOR SELECTION					N:1 TDI	COMBINATION SELECTED
	1	2	3	4	5	6	7	8	1	2	3	4	DET		
37	0	0	1	0	0	1	0	1	4	0	0	0	1	1	4*Det1
39	0	0	1	0	0	1	1	1	4	0	0	0	1	1	4*Det1
45	0	0	1	0	1	1	0	1	4	0	0	0	1	1	4*Det1
47	0	0	1	0	1	1	1	1	4	0	0	0	1	1	4*Det1
88	0	1	0	1	1	0	0	0	0	4	0	0	2	1	4*Det2
120	0	1	1	1	1	0	0	0	0	4	0	0	2	1	4*Det2
216	1	1	0	1	1	0	0	0	0	4	0	0	2	1	4*Det2
248	1	1	1	1	1	0	0	0	0	4	0	0	2	1	4*Det2
82	0	1	0	1	0	0	1	0	0	0	4	0	3	1	4*Det3
114	0	1	1	1	0	0	1	0	0	0	4	0	3	1	4*Det3
210	1	1	0	1	0	0	1	0	0	0	4	0	3	1	4*Det3
242	1	1	1	1	0	0	1	0	0	0	4	0	3	1	4*Det3
133	1	0	0	0	0	1	0	1	0	0	0	4	4	1	4*Det4
135	1	0	0	0	0	1	1	1	0	0	0	4	4	1	4*Det4
141	1	0	0	0	1	1	0	1	0	0	0	4	4	1	4*Det4
143	1	0	0	0	1	1	1	1	0	0	0	4	4	1	4*Det4
20	0	0	0	1	0	1	0	0	2	2	0	0	12	2	2*Det1 + 2*Det2
28	0	0	0	1	1	1	0	0	2	2	0	0	12	2	2*Det1 + 2*Det2
40	0	0	1	0	1	0	0	0	2	2	0	0	12	2	2*Det1 + 2*Det2
52	0	0	1	1	0	1	0	0	2	2	0	0	12	2	2*Det1 + 2*Det2
57	0	0	1	1	1	0	0	1	2	2	0	0	12	2	2*Det1 + 2*Det2
60	0	0	1	1	1	1	0	0	2	2	0	0	12	2	2*Det1 + 2*Det2
105	0	1	1	0	1	0	0	1	2	2	0	0	12	2	2*Det1 + 2*Det2
107	0	1	1	0	1	0	1	1	2	2	0	0	12	2	2*Det1 + 2*Det2
108	0	1	1	0	1	1	0	0	2	2	0	0	12	2	2*Det1 + 2*Det2
125	0	1	1	1	1	1	0	1	2	2	0	0	12	2	2*Det1 + 2*Det2
233	1	1	1	0	1	0	0	1	2	2	0	0	12	2	2*Det1 + 2*Det2
235	1	1	1	0	1	0	1	1	2	2	0	0	12	2	2*Det1 + 2*Det2
22	0	0	0	1	0	1	1	0	2	0	2	0	13	2	2*Det1 + 2*Det3
30	0	0	0	1	1	1	1	0	2	0	2	0	13	2	2*Det1 + 2*Det3
34	0	0	1	0	0	0	1	0	2	0	2	0	13	2	2*Det1 + 2*Det3
51	0	0	1	1	0	0	1	1	2	0	2	0	13	2	2*Det1 + 2*Det3
54	0	0	1	1	0	1	1	0	2	0	2	0	13	2	2*Det1 + 2*Det3
62	0	0	1	1	1	1	1	0	2	0	2	0	13	2	2*Det1 + 2*Det3
97	0	1	1	0	0	0	0	1	2	0	2	0	13	2	2*Det1 + 2*Det3
99	0	1	1	0	0	0	1	1	2	0	2	0	13	2	2*Det1 + 2*Det3
102	0	1	1	0	0	1	1	0	2	0	2	0	13	2	2*Det1 + 2*Det3
119	0	1	1	1	0	1	1	1	2	0	2	0	13	2	2*Det1 + 2*Det3
225	1	1	1	0	0	0	0	1	2	0	2	0	13	2	2*Det1 + 2*Det3
227	1	1	1	0	0	0	1	1	2	0	2	0	13	2	2*Det1 + 2*Det3
5	0	0	0	0	0	1	0	1	2	0	0	2	14	2	2*Det1 + 2*Det4
7	0	0	0	0	0	1	1	1	2	0	0	2	14	2	2*Det1 + 2*Det4
13	0	0	0	0	1	1	0	1	2	0	0	2	14	2	2*Det1 + 2*Det4
15	0	0	0	0	1	1	1	1	2	0	0	2	14	2	2*Det1 + 2*Det4
165	1	0	1	0	0	1	0	1	2	0	0	2	14	2	2*Det1 + 2*Det4
167	1	0	1	0	0	1	1	1	2	0	0	2	14	2	2*Det1 + 2*Det4
173	1	0	1	0	1	1	0	1	2	0	0	2	14	2	2*Det1 + 2*Det4
175	1	0	1	0	1	1	1	1	2	0	0	2	14	2	2*Det1 + 2*Det4

Table B-3: SeaWiFS TDI Telemetry List Sorted By TDI Level and Combination (cont'd)

DEC #	BAND X TDI BIT								DETECTOR SELECTION					N:1 TDI	COMBINATION SELECTED
	1	2	3	4	5	6	7	8	1	2	3	4	DET		
80	0	1	0	1	0	0	0	0	0	2	2	0	23	2	2*Det2 + 2*Det3
90	0	1	0	1	1	0	1	0	0	2	2	0	23	2	2*Det2 + 2*Det3
112	0	1	1	1	0	0	0	0	0	2	2	0	23	2	2*Det2 + 2*Det3
122	0	1	1	1	1	0	1	0	0	2	2	0	23	2	2*Det2 + 2*Det3
208	1	1	0	1	0	0	0	0	0	2	2	0	23	2	2*Det2 + 2*Det3
218	1	1	0	1	1	0	1	0	0	2	2	0	23	2	2*Det2 + 2*Det3
240	1	1	1	1	0	0	0	0	0	2	2	0	23	2	2*Det2 + 2*Det3
250	1	1	1	1	1	0	1	0	0	2	2	0	23	2	2*Det2 + 2*Det3
73	0	1	0	0	1	0	0	1	0	2	0	2	24	2	2*Det2 + 2*Det4
75	0	1	0	0	1	0	1	1	0	2	0	2	24	2	2*Det2 + 2*Det4
136	1	0	0	0	1	0	0	0	0	2	0	2	24	2	2*Det2 + 2*Det4
148	1	0	0	1	0	1	0	0	0	2	0	2	24	2	2*Det2 + 2*Det4
153	1	0	0	1	1	0	0	1	0	2	0	2	24	2	2*Det2 + 2*Det4
156	1	0	0	1	1	1	0	0	0	2	0	2	24	2	2*Det2 + 2*Det4
180	1	0	1	1	0	1	0	0	0	2	0	2	24	2	2*Det2 + 2*Det4
188	1	0	1	1	1	1	0	0	0	2	0	2	24	2	2*Det2 + 2*Det4
201	1	1	0	0	1	0	0	1	0	2	0	2	24	2	2*Det2 + 2*Det4
203	1	1	0	0	1	0	1	1	0	2	0	2	24	2	2*Det2 + 2*Det4
204	1	1	0	0	1	1	0	0	0	2	0	2	24	2	2*Det2 + 2*Det4
221	1	1	0	1	1	1	0	1	0	2	0	2	24	2	2*Det2 + 2*Det4
65	0	1	0	0	0	0	0	1	0	0	2	2	34	2	2*Det3 + 2*Det4
67	0	1	0	0	0	0	1	1	0	0	2	2	34	2	2*Det3 + 2*Det4
130	1	0	0	0	0	0	1	0	0	2	2	2	34	2	2*Det3 + 2*Det4
147	1	0	0	1	0	0	1	1	0	0	2	2	34	2	2*Det3 + 2*Det4
150	1	0	0	1	0	1	1	0	0	0	2	2	34	2	2*Det3 + 2*Det4
158	1	0	0	1	1	1	1	0	0	0	2	2	34	2	2*Det3 + 2*Det4
182	1	0	1	1	0	1	1	0	0	0	2	2	34	2	2*Det3 + 2*Det4
190	1	0	1	1	1	1	1	0	0	0	2	2	34	2	2*Det3 + 2*Det4
193	1	1	0	0	0	0	0	1	0	0	2	2	34	2	2*Det3 + 2*Det4
195	1	1	0	0	0	0	1	1	0	0	2	2	34	2	2*Det3 + 2*Det4
198	1	1	0	0	0	1	1	0	0	0	2	2	34	2	2*Det3 + 2*Det4
215	1	1	0	1	0	1	1	1	0	0	2	2	34	2	2*Det3 + 2*Det4
36	0	0	1	0	0	1	0	0	3	1	0	0	12	2	3*Det1 + Det2
41	0	0	1	0	1	0	0	1	3	1	0	0	12	2	3*Det1 + Det2
43	0	0	1	0	1	0	1	1	3	1	0	0	12	2	3*Det1 + Det2
44	0	0	1	0	1	1	0	0	3	1	0	0	12	2	3*Det1 + Det2
53	0	0	1	1	0	1	0	1	3	1	0	0	12	2	3*Det1 + Det2
61	0	0	1	1	1	1	0	1	3	1	0	0	12	2	3*Det1 + Det2
109	0	1	1	0	1	1	0	1	3	1	0	0	12	2	3*Det1 + Det2
111	0	1	1	0	1	1	1	1	3	1	0	0	12	2	3*Det1 + Det2
33	0	0	1	0	0	0	0	1	3	0	1	0	13	2	3*Det1 + Det3
35	0	0	1	0	0	0	1	1	3	0	1	0	13	2	3*Det1 + Det3
38	0	0	1	0	0	1	1	0	3	0	1	0	13	2	3*Det1 + Det3
46	0	0	1	0	1	1	1	0	3	0	1	0	13	2	3*Det1 + Det3
55	0	0	1	1	0	1	1	1	3	0	1	0	13	2	3*Det1 + Det3
63	0	0	1	1	1	1	1	1	3	0	1	0	13	2	3*Det1 + Det3
101	0	1	1	0	0	1	0	1	3	0	1	0	13	2	3*Det1 + Det3
103	0	1	1	0	0	1	1	1	3	0	1	0	13	2	3*Det1 + Det3

Table B-3: SeaWiFS TDI Telemetry List Sorted By TDI Level and Combination (cont'd)

DEC #	BAND X TDI BIT								DETECTOR SELECTION					N:1 TDI	COMBINATION SELECTED
	1	2	3	4	5	6	7	8	1	2	3	4	DET		
72	0	1	0	0	1	0	0	0	0	3	0	1	24	2	3*Det2 + Det4
89	0	1	0	1	1	0	0	1	0	3	0	1	24	2	3*Det2 + Det4
152	1	0	0	1	1	0	0	0	0	3	0	1	24	2	3*Det2 + Det4
184	1	0	1	1	1	0	0	0	0	3	0	1	24	2	3*Det2 + Det4
200	1	1	0	0	1	0	0	0	0	3	0	1	24	2	3*Det2 + Det4
217	1	1	0	1	1	0	0	1	0	3	0	1	24	2	3*Det2 + Det4
220	1	1	0	1	1	1	0	0	0	3	0	1	24	2	3*Det2 + Det4
249	1	1	1	1	1	0	0	1	0	3	0	1	24	2	3*Det2 + Det4
252	1	1	1	1	1	1	0	0	0	3	0	1	24	2	3*Det2 + Det4
66	0	1	0	0	0	0	1	0	0	0	3	1	34	2	3*Det3 + Det4
83	0	1	0	1	0	0	1	1	0	0	3	1	34	2	3*Det3 + Det4
146	1	0	0	1	0	0	1	0	0	0	3	1	34	2	3*Det3 + Det4
178	1	0	1	1	0	0	1	0	0	0	3	1	34	2	3*Det3 + Det4
194	1	1	0	0	0	0	1	0	0	0	3	1	34	2	3*Det3 + Det4
211	1	1	0	1	0	0	1	1	0	0	3	1	34	2	3*Det3 + Det4
214	1	1	0	1	0	1	1	0	0	0	3	1	34	2	3*Det3 + Det4
246	1	1	1	1	0	1	1	0	0	0	3	1	34	2	3*Det3 + Det4
24	0	0	0	1	1	0	0	0	1	3	0	0	12	2	Det1 + 3*Det2
56	0	0	1	1	1	0	0	0	1	3	0	0	12	2	Det1 + 3*Det2
92	0	1	0	1	1	1	0	0	1	3	0	0	12	2	Det1 + 3*Det2
104	0	1	1	0	1	0	0	0	1	3	0	0	12	2	Det1 + 3*Det2
121	0	1	1	1	1	0	0	1	1	3	0	0	12	2	Det1 + 3*Det2
124	0	1	1	1	1	1	0	0	1	3	0	0	12	2	Det1 + 3*Det2
232	1	1	1	0	1	0	0	0	1	3	0	0	12	2	Det1 + 3*Det2
18	0	0	0	1	0	0	1	0	1	0	3	0	13	2	Det1 + 3*Det3
50	0	0	1	1	0	0	1	0	1	0	3	0	13	2	Det1 + 3*Det3
86	0	1	0	1	0	1	1	0	1	0	3	0	13	2	Det1 + 3*Det3
98	0	1	1	0	0	0	1	0	1	0	3	0	13	2	Det1 + 3*Det3
115	0	1	1	1	0	0	1	1	1	0	3	0	13	2	Det1 + 3*Det3
118	0	1	1	1	0	1	1	0	1	0	3	0	13	2	Det1 + 3*Det3
226	1	1	1	0	0	0	1	0	1	0	3	0	13	2	Det1 + 3*Det3
243	1	1	1	1	0	0	1	1	1	0	3	0	13	2	Det1 + 3*Det3
132	1	0	0	0	0	1	0	0	0	1	0	3	24	2	Det2 + 3*Det4
137	1	0	0	0	1	0	0	1	0	1	0	3	24	2	Det2 + 3*Det4
139	1	0	0	0	1	0	1	1	0	1	0	3	24	2	Det2 + 3*Det4
140	1	0	0	0	1	1	0	0	0	1	0	3	24	2	Det2 + 3*Det4
149	1	0	0	1	0	1	0	1	0	1	0	3	24	2	Det2 + 3*Det4
157	1	0	0	1	1	1	0	1	0	1	0	3	24	2	Det2 + 3*Det4
205	1	1	0	0	1	1	0	1	0	1	0	3	24	2	Det2 + 3*Det4
207	1	1	0	0	1	1	1	1	0	1	0	3	24	2	Det2 + 3*Det4
129	1	0	0	0	0	0	0	1	0	0	1	3	34	2	Det3 + 3*Det4
131	1	0	0	0	0	0	1	1	0	0	1	3	34	2	Det3 + 3*Det4
134	1	0	0	0	0	1	1	0	0	0	1	3	34	2	Det3 + 3*Det4
142	1	0	0	0	1	1	1	0	0	0	1	3	34	2	Det3 + 3*Det4
151	1	0	0	1	0	1	1	1	0	0	1	3	34	2	Det3 + 3*Det4
159	1	0	0	1	1	1	1	1	0	0	1	3	34	2	Det3 + 3*Det4
197	1	1	0	0	0	1	0	1	0	0	1	3	34	2	Det3 + 3*Det4
199	1	1	0	0	0	1	1	1	0	0	1	3	34	2	Det3 + 3*Det4

Table B-3: SeaWiFS TDI Telemetry List Sorted By TDI Level and Combination (cont'd)

DEC #	BAND X TDI BIT								DETECTOR SELECTION					N:1 TDI	COMBINATION SELECTED
	1	2	3	4	5	6	7	8	1	2	3	4	DET		
32	0	0	1	0	0	0	0	0	2	1	1	0	123	3	2*Det1 + Det2 + Det3
42	0	0	1	0	1	0	1	0	2	1	1	0	123	3	2*Det1 + Det2 + Det3
49	0	0	1	1	0	0	0	1	2	1	1	0	123	3	2*Det1 + Det2 + Det3
59	0	0	1	1	1	0	1	1	2	1	1	0	123	3	2*Det1 + Det2 + Det3
100	0	1	1	0	0	1	0	0	2	1	1	0	123	3	2*Det1 + Det2 + Det3
110	0	1	1	0	1	1	1	0	2	1	1	0	123	3	2*Det1 + Det2 + Det3
117	0	1	1	1	0	1	0	1	2	1	1	0	123	3	2*Det1 + Det2 + Det3
127	0	1	1	1	1	1	1	1	2	1	1	0	123	3	2*Det1 + Det2 + Det3
4	0	0	0	0	0	1	0	0	2	1	0	1	124	3	2*Det1 + Det2 + Det4
12	0	0	0	0	1	1	0	0	2	1	0	1	124	3	2*Det1 + Det2 + Det4
21	0	0	0	1	0	1	0	1	2	1	0	1	124	3	2*Det1 + Det2 + Det4
29	0	0	0	1	1	1	0	1	2	1	0	1	124	3	2*Det1 + Det2 + Det4
169	1	0	1	0	1	0	0	1	2	1	0	1	124	3	2*Det1 + Det2 + Det4
171	1	0	1	0	1	0	1	1	2	1	0	1	124	3	2*Det1 + Det2 + Det4
237	1	1	1	0	1	1	0	1	2	1	0	1	124	3	2*Det1 + Det2 + Det4
239	1	1	1	0	1	1	1	1	2	1	0	1	124	3	2*Det1 + Det2 + Det4
6	0	0	0	0	0	1	1	0	2	0	1	1	134	3	2*Det1 + Det3 + Det4
14	0	0	0	0	1	1	1	0	2	0	1	1	134	3	2*Det1 + Det3 + Det4
23	0	0	0	1	0	1	1	1	2	0	1	1	134	3	2*Det1 + Det3 + Det4
31	0	0	0	1	1	1	1	1	2	0	1	1	134	3	2*Det1 + Det3 + Det4
161	1	0	1	0	0	0	0	1	2	0	1	1	134	3	2*Det1 + Det3 + Det4
163	1	0	1	0	0	0	1	1	2	0	1	1	134	3	2*Det1 + Det3 + Det4
229	1	1	1	0	0	1	0	1	2	0	1	1	134	3	2*Det1 + Det3 + Det4
231	1	1	1	0	0	1	1	1	2	0	1	1	134	3	2*Det1 + Det3 + Det4
74	0	1	0	0	1	0	1	0	0	2	1	1	234	3	2*Det2 + Det3 + Det4
91	0	1	0	1	1	0	1	1	0	2	1	1	234	3	2*Det2 + Det3 + Det4
144	1	0	0	1	0	0	0	0	0	2	1	1	234	3	2*Det2 + Det3 + Det4
176	1	0	1	1	0	0	0	0	0	2	1	1	234	3	2*Det2 + Det3 + Det4
202	1	1	0	0	1	0	1	0	0	2	1	1	234	3	2*Det2 + Det3 + Det4
212	1	1	0	1	0	1	0	0	0	2	1	1	234	3	2*Det2 + Det3 + Det4
219	1	1	0	1	1	0	1	1	0	2	1	1	234	3	2*Det2 + Det3 + Det4
244	1	1	1	1	0	1	0	0	0	2	1	1	234	3	2*Det2 + Det3 + Det4
16	0	0	0	1	0	0	0	0	1	2	1	0	123	3	Det1 + 2*Det2 + Det3
48	0	0	1	1	0	0	0	0	1	2	1	0	123	3	Det1 + 2*Det2 + Det3
84	0	1	0	1	0	1	0	0	1	2	1	0	123	3	Det1 + 2*Det2 + Det3
106	0	1	1	0	1	0	1	0	1	2	1	0	123	3	Det1 + 2*Det2 + Det3
116	0	1	1	1	0	1	0	0	1	2	1	0	123	3	Det1 + 2*Det2 + Det3
123	0	1	1	1	1	0	1	1	1	2	1	0	123	3	Det1 + 2*Det2 + Det3
234	1	1	1	0	1	0	1	0	1	2	1	0	123	3	Det1 + 2*Det2 + Det3
251	1	1	1	1	1	0	1	1	1	2	1	0	123	3	Det1 + 2*Det2 + Det3
8	0	0	0	0	1	0	0	0	1	2	0	1	124	3	Det1 + 2*Det2 + Det4
25	0	0	0	1	1	0	0	1	1	2	0	1	124	3	Det1 + 2*Det2 + Det4
76	0	1	0	0	1	1	0	0	1	2	0	1	124	3	Det1 + 2*Det2 + Det4
93	0	1	0	1	1	1	0	1	1	2	0	1	124	3	Det1 + 2*Det2 + Det4
168	1	0	1	0	1	0	0	0	1	2	0	1	124	3	Det1 + 2*Det2 + Det4
185	1	0	1	1	1	0	0	1	1	2	0	1	124	3	Det1 + 2*Det2 + Det4
236	1	1	1	0	1	1	0	0	1	2	0	1	124	3	Det1 + 2*Det2 + Det4
253	1	1	1	1	1	1	0	1	1	2	0	1	124	3	Det1 + 2*Det2 + Det4

Table B-3: SeaWiFS TDI Telemetry List Sorted By TDI Level and Combination (cont'd)

DEC #	BAND X TDI BIT								DETECTOR SELECTION					N:1 TDI	COMBINATION SELECTED
	1	2	3	4	5	6	7	8	1	2	3	4	DET		
2	0	0	0	0	0	0	1	0	1	0	2	1	124	3	Det1 + 2*Det3 + Det4
19	0	0	0	1	0	0	1	1	1	0	2	1	134	3	Det1 + 2*Det3 + Det4
70	0	1	0	0	0	1	1	0	1	0	2	1	134	3	Det1 + 2*Det3 + Det4
87	0	1	0	1	0	1	1	1	1	0	2	1	134	3	Det1 + 2*Det3 + Det4
162	1	0	1	0	0	0	1	0	1	0	2	1	134	3	Det1 + 2*Det3 + Det4
179	1	0	1	1	0	0	1	1	1	0	2	1	134	3	Det1 + 2*Det3 + Det4
230	1	1	1	0	0	1	1	0	1	0	2	1	134	3	Det1 + 2*Det3 + Det4
247	1	1	1	1	0	1	1	1	1	0	2	1	134	3	Det1 + 2*Det3 + Det4
26	0	0	0	1	1	0	1	0	1	1	2	0	123	3	Det1 + Det2 + 2*Det3
58	0	0	1	1	1	0	1	0	1	1	2	0	123	3	Det1 + Det2 + 2*Det3
94	0	1	0	1	1	1	1	0	1	1	2	0	123	3	Det1 + Det2 + 2*Det3
96	0	1	1	0	0	0	0	0	1	1	2	0	123	3	Det1 + Det2 + 2*Det3
113	0	1	1	1	0	0	0	1	1	1	2	0	123	3	Det1 + Det2 + 2*Det3
126	0	1	1	1	1	1	1	0	1	1	2	0	123	3	Det1 + Det2 + 2*Det3
224	1	1	1	0	0	0	0	0	1	1	2	0	123	3	Det1 + Det2 + 2*Det3
241	1	1	1	1	0	0	0	1	1	1	2	0	123	3	Det1 + Det2 + 2*Det3
9	0	0	0	0	1	0	0	1	1	1	0	2	124	3	Det1 + Det2 + 2*Det4
11	0	0	0	0	1	0	1	1	1	1	0	2	124	3	Det1 + Det2 + 2*Det4
77	0	1	0	0	1	1	0	1	1	1	0	2	124	3	Det1 + Det2 + 2*Det4
79	0	1	0	0	1	1	1	1	1	1	0	2	124	3	Det1 + Det2 + 2*Det4
164	1	0	1	0	0	1	0	0	1	1	0	2	124	3	Det1 + Det2 + 2*Det4
172	1	0	1	0	1	1	0	0	1	1	0	2	124	3	Det1 + Det2 + 2*Det4
181	1	0	1	1	0	1	0	1	1	1	0	2	124	3	Det1 + Det2 + 2*Det4
189	1	0	1	1	1	1	0	1	1	1	0	2	124	3	Det1 + Det2 + 2*Det4
1	0	0	0	0	0	0	0	1	1	0	1	2	134	3	Det1 + Det3 + 2*Det4
3	0	0	0	0	0	0	1	1	1	0	1	2	134	3	Det1 + Det3 + 2*Det4
69	0	1	0	0	0	1	0	1	1	0	1	2	134	3	Det1 + Det3 + 2*Det4
71	0	1	0	0	0	1	1	1	1	0	1	2	134	3	Det1 + Det3 + 2*Det4
166	1	0	1	0	0	1	1	0	1	0	1	2	134	3	Det1 + Det3 + 2*Det4
174	1	0	1	0	1	1	1	0	1	0	1	2	134	3	Det1 + Det3 + 2*Det4
183	1	0	1	1	0	1	1	1	1	0	1	2	134	3	Det1 + Det3 + 2*Det4
191	1	0	1	1	1	1	1	1	1	0	1	2	134	3	Det1 + Det3 + 2*Det4
64	0	1	0	0	0	0	0	0	0	1	2	1	234	3	Det2 + 2*Det3 + Det4
81	0	1	0	1	0	0	0	1	0	1	2	1	234	3	Det2 + 2*Det3 + Det4
154	1	0	0	1	1	0	1	0	0	1	2	1	234	3	Det2 + 2*Det3 + Det4
186	1	0	1	1	1	0	1	0	0	1	2	1	234	3	Det2 + 2*Det3 + Det4
192	1	1	0	0	0	0	0	0	0	1	2	1	234	3	Det2 + 2*Det3 + Det4
209	1	1	0	1	0	0	0	1	0	1	2	1	234	3	Det2 + 2*Det3 + Det4
222	1	1	0	1	1	1	1	0	0	1	2	1	234	3	Det2 + 2*Det3 + Det4
254	1	1	1	1	1	1	1	0	0	1	2	1	234	3	Det2 + 2*Det3 + Det4
128	1	0	0	0	0	0	0	0	0	1	1	2	234	3	Det2 + Det3 + 2*Det4
138	1	0	0	0	1	0	1	0	0	1	1	2	234	3	Det2 + Det3 + 2*Det4
145	1	0	0	1	0	0	0	1	0	1	1	2	234	3	Det2 + Det3 + 2*Det4
155	1	0	0	1	1	0	1	1	0	1	1	2	234	3	Det2 + Det3 + 2*Det4
196	1	1	0	0	0	1	0	0	0	1	1	2	234	3	Det2 + Det3 + 2*Det4
206	1	1	0	0	1	1	1	0	0	1	1	2	234	3	Det2 + Det3 + 2*Det4
213	1	1	0	1	0	1	0	1	0	1	1	2	234	3	Det2 + Det3 + 2*Det4
223	1	1	0	1	1	1	1	1	0	1	1	2	234	3	Det2 + Det3 + 2*Det4

**Table B-3: SeaWiFS TDI Telemetry List Sorted By TDI Level and Combination
(cont'd)**

DEC #	BAND X TDI BIT								DETECTOR SELECTION					N:1 TDI	COMBINATION SELECTED
	1	2	3	4	5	6	7	8	1	2	3	4	DET		
0	0	0	0	0	0	0	0	0	1	1	1	1	1234	4	Det1 + Det2 + Det3 + Det4
10	0	0	0	0	1	0	1	0	1	1	1	1	1234	4	Det1 + Det2 + Det3 + Det4
17	0	0	0	1	0	0	0	1	1	1	1	1	1234	4	Det1 + Det2 + Det3 + Det4
27	0	0	0	1	1	0	1	1	1	1	1	1	1234	4	Det1 + Det2 + Det3 + Det4
68	0	1	0	0	0	1	0	0	1	1	1	1	1234	4	Det1 + Det2 + Det3 + Det4
78	0	1	0	0	1	1	1	0	1	1	1	1	1234	4	Det1 + Det2 + Det3 + Det4
85	0	1	0	1	0	1	0	1	1	1	1	1	1234	4	Det1 + Det2 + Det3 + Det4
95	0	1	0	1	1	1	1	1	1	1	1	1	1234	4	Det1 + Det2 + Det3 + Det4
160	1	0	1	0	0	0	0	0	1	1	1	1	1234	4	Det1 + Det2 + Det3 + Det4
170	1	0	1	0	1	0	1	0	1	1	1	1	1234	4	Det1 + Det2 + Det3 + Det4
177	1	0	1	1	0	0	0	1	1	1	1	1	1234	4	Det1 + Det2 + Det3 + Det4
187	1	0	1	1	1	0	1	1	1	1	1	1	1234	4	Det1 + Det2 + Det3 + Det4
228	1	1	1	0	0	1	0	0	1	1	1	1	1234	4	Det1 + Det2 + Det3 + Det4
238	1	1	1	0	1	1	1	0	1	1	1	1	1234	4	Det1 + Det2 + Det3 + Det4
245	1	1	1	1	0	1	0	1	1	1	1	1	1234	4	Det1 + Det2 + Det3 + Det4
255	1	1	1	1	1	1	1	1	1	1	1	1	1234	4	Det1 + Det2 + Det3 + Det4

APPENDIX C

L-BAND LINK BUDGET ANALYSIS

Table C-1. L-Band Link Budget Analysis

HRPT Nadir Boresight Point Via Spacecraft High Gain Antenna

DLINK PARAMETERS:

Real-time Frequency:	1702.5 MHz	(L-Band RHCP)
Real-time Bit Rate:	1.3308 Mbps	(Manchester Bit Rate = Data Rate *2)
Real-time Transmit Power:	5 W	
Vehicle Line Losses:	1.7 dB	
Mea. Spacecraft Ant. Gain (L-Band):	3.0 dBiC	(1 std. deviation below median gain)
Slant Range:	2575.0 km	(705km ht, 5 deg)
Polarization Losses:	-0.5 dB	(3 dB AR grn. ant.)
Atmospheric Losses:	-0.5 dB	
Pointing Losses:	-0.1 dB	
Ground Antenna L-Band G/T:	6.5 dB/K	(As Per NASA Contract)
Subcarrier Modulation Index:	67.5 degrees	TIROS-N Standard
Required TLM SNR:	10.7 dB	(10e-6 BER)
Hardware BER Losses:	1.0 dB	

LINK CALCULATION:

<u>TOTAL POWER TO GROUND:</u>	<u>OSC's SeaStar TT&C Ground Station</u>	<u>NASA Specified HRPT Ground Station</u>
Satellite Transmitter Power:	37.0 dBm	37.0 dBm
Spacecraft Line Losses:	-1.7 dB	-1.7 dB
Spacecraft Antenna Gain:	3.0 dBiC	3.0 dBiC
Path Loss at 5 degrees above Horizon:	-165.3 dB	-165.3 dB
Polarization Loss:	-0.5 dB	-0.5 dB
Atmospheric Loss:	-0.5 dB	-0.5 dB
Pointing Loss:	-0.1 dB	-0.1 dB
Isotropic Signal at Ground:	-128.1 dBm	-128.1 dBm

REQUIRED POWER AT GROUND:

Boltzmann's Constant:	-198.6 dBm/K-Hz	-198.6 dBm/K-Hz
Ground Antenna G/T:	11.8 dB/K	6.5 dB/K
Residual Carrier Loss	-0.2 dB	-0.2 dB
Mod Loss Due To Carrier:	-0.7 dB	-0.7 dB
Noise Bandwidth:	61.2 dBHz	61.2 dBHz
Required SNR:	10.7 dB	10.7 dB
Hardware BER Losses:	-1.0 dB	-1.0 dB
Required Service Power:	-136.6 dBm	-131.3 dBm
DLINK MARGIN:	8.5 dB	3.2 dB

APPENDIX D

PRECISE SEAWIFS TEMPERATURE TELEMETRY CONVERSION

Each SeaWiFS telemetry output used a precision negative temperature coefficient (NRT) thermistor (10 Kohms at 25°C, accuracy <0.1°C) which is paralleled by a 16.2 Kohm resistor, driven by a current source diode that is nominally 0.48 millamps and buffered by a non-inverting unity gain op-amp. The SeaWiFS temperature telemetry voltage outputs are read by the SeaWiFS Interface Unit (SIU) and converted into 8-bit digital values (256 digital counts). Inside the SIU, all SeaWiFS analog telemetry signals are switched through a set of analog multiplexers to a single high speed, eight bit analog-to-digital converter. An active clamping circuit between the multiplexers and the A-to-D converter protects the converter against being exposed to potentially damaging voltages in the case of a SeaWiFS electronics failure. This clamping circuit also introduces an error of no more than ±1 LSB in the linear conversion region.

The 8-bit SeaWiFS temperature telemetry from the SIU is inserted into the instrument telemetry field of the HRPT data streams (real time LAC and stored LAC and GAC). The temperature telemetry voltages VT(X) are converted from digital to analog values using the expression in equation 2 (see below).

Temperature telemetry voltages (VTx) are converted to temperature by dividing the telemetry voltage by the current source value (I_{X20}) to get an effective resistance (REx). Next, the actual thermistor resistance (RTx) is calculated from the effective resistance and finally, the thermistor resistance is converted to temperature using a conversion formula. Table D-1 lists the temperature telemetry and their I_{X20} currents. Note that Primary and Redundant Telemetry have different I_{X20} values. Because the current sources have a slightly negative temperature dependance, the first formula includes a correction term multiplied by the difference between 20°C and Tc; Tc is the temperature of the telemetry CCA which can be estimated by using the raw B1_B2_POSTAMP_TEMP telemetry voltage VT_{A2} per equation 3. The value of VT_{A2} in equation 3 is obtained from equation 1. So the whole “cookbook” process used to obtain precise SeaWiFS temperatures is:

1. Convert temperature telemetry voltage for sensor A2 from digital DVT_{A2} to analog VT_{A2} units:

$$VT_{A2} = DVT_{A2} \times 5.12V \div 256 \text{ digital counts}$$

2. Convert all other temperature telemetry voltages from digital DVT_x to analog VT_x units:

$$VT_x = DVT_x \times 5.12 \div 256 \text{ digital counts}$$

NOTE: Equations 1 and 2 are only valid for DVT() values in the range of 25 to 225 counts. This is equivalent to a valid temperature range between 7 and 85 deg C. Outside of that range, the analog telemetry sampling functions become nonlinear due to the behavior of the A-to-D protection clamping circuit.

3. Calculate T_c :

$$T_c = (5 - V T_{A2}) \times \frac{40}{3} \quad [\text{useable for module temperatures from } 5^\circ\text{C to } 40^\circ\text{C}]$$

4. Calculate R_{Ex} for each temperature sensor:

$$R_{Ex} = \frac{V T_x}{I_{x20} - (0.0013) \times (T_c - 20)} \quad (\text{Kohms}) \text{ where } T_c \text{ is A2 CCA temp (default } = 20^\circ\text{C)}$$

[I_{x20} is in milliamps]

5. Calculate R_{Tx} for each temperature sensor:

$$R_{Tx} = \frac{16.2 \times R_{Ex}}{16.2 - R_{Ex}} \quad (\text{Kohms})$$

6. Calculate temperature T_x :

$$T_x = \frac{5398.94}{\ln(254898 \times R_{Tx})} - 341 \quad (\text{ }^\circ\text{C}) \quad \text{note that } R_{Tx} \text{ is in Kohms}$$

Table D-1. Temperature Telemetry Coefficients

NO.	NAME	PRI I20	RDT I20
1	BAND_1_2_FPA_TEMP	0.493	0.484
2	BAND_3_4_FPA_TEMP	0.492	0.496*
3	BAND_5_6_FPA_TEMP	0.491	0.497
4	BAND_7_8_FPA_TEMP	0.486	0.492
25	TELESCOPE_MOTOR_TEMP	0.492	0.483
26	TILT_PLAT_TEMP	0.489	0.515
27	TILT_BASE_TEMP	0.475	0.496
28	HALF_ANG_MIRROR_MOTOR_TEM P	0.485	0.478
29	PS_TEMP	0.483	0.502
30	SERVO_DRIVER_TEMP	0.481	0.510
31	BAND_1_2_POSTAMP_TEMP	0.473	0.512

* Sensor open after cloud channel rework

$T_c=20^\circ\text{C}$

Correcting for the temperature dependance of the individual current sources is required only when the module temperature is not near 20°C. Use of the algorithm described above will provide accurate temperature to within the digitizing level of the telemetry system (~0.1 degree) over the range of +7°C to 45°C. Below 7°C, the temperature telemetry becomes inaccurate due to the clamping circuit in the SIU. Above +50°C the accuracy drops as the changes in thermistor resistance per degree C become much smaller.

Figure D-2 compares the temperature predictions based on the algorithm provided above and the simplified linear approximation. The linear curve bit is within a few degrees C accuracy of the precise prediction for temperatures between 7°C to 40°C.

Figure D-2. SeaWiFS Temperature Conversion Example
Band 1/2 FPA Temperature, Primary Side

Note: Assume $T_c=20C$; does not include clamping circuit effects

